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A PERFORMANCE IMPROVEMENT FRAMEWORK FOR LEAN PROJECT PROCUREMENT AND ON-SITE MATERIAL MANAGEMENT

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Master in Applied Management

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June 2023

BUSINESS
SCHOOL

Department of Marketing, Operations and General Management

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Acknowledgements

This thesis was completed under the careful guidance of Prof. Henrique O'Neill. From the selection of the topic of the paper, the writing structure, the research methodology, the collection of some foreign references, and the process of repeated revisions to the final paper, Professor Henrique O'Neill's heart and soul were all involved. Your attitude, academic thinking and professionalism have left a deep memory for me. I am very grateful to Prof. Henrique O'Neill for your advice and guidance in completing my dissertation, and you have opened my eyes to what action research methodology is, which has opened new horizons for me to solve organizational problems in my work, and this methodology has been of great benefit to me.

I would like to thank the faculty team for their help and support in writing my dissertation.

I would like to thank all the experts and judges who participated in the review and defense of my dissertation.

Finally, I would like to thank the people who have supported and helped me in my studies, and I wish you all the best.

Abstract

In the increasingly competitive construction industry, reducing waste has been a major concern for organizations and managers, especially in design, procurement and materials management.

This paper uses an action research approach (a very common research method for studying organizational development issues) around the research question and develops a proposed framework that integrates BIM technology, lean thinking, and advanced management processes based on the steps and roadmap of the action research approach. The objective is to use the framework to target wasteful project behaviors and help projects gain more from procurement and materials management.

To develop the proposal framework, interviews were first conducted with the company's middle and senior management, and the feedback data from the interviews were used to verify consistency with the authors' pre-determined questions as the basis for the proposal framework.

The authorverified the feasibility of the proposed framework implementation through online questionnaire data collection. The process was centered around six dimensions of the proposed framework, including comprehension, rationality, effectiveness, acceptability, implementability, and support, and the majority of respondents reached consensus on the framework's feasibility. Also, respondents recommended getting commitment from project managers to develop an illustrative guide to Lean knowledge prior to framework implementation to improve implementation efficiency.

The results of the study indicate that the proposed framework is feasible and can be implemented in the next step of action research. The framework provides a new approach to address organizational development.

Keywords: Action Research, Lean Thinking, Proposed Framework, BIM, Procurement, Material Management

JEL Classification: M19, Y40

Resumo

No sector da construção, cada vez mais competitivo, a redução do desperdício tem sido uma preocupação constante das organizações e dos gestores, em especial nos domínios da concepção, do aprovisionamento e da gestão de materiais.

O presente documento utiliza uma abordagem de investigação-acção, em torno da questão de investigação e com base nas etapas da metodologia de investigação-acção, para propor um framework que incorpora técnicas BIM, pensamento "*lean*" e processos de gestão avançados, com o objectivo de ajudar os projectos a tirar maior partido da aquisição e gestão de materiais.

Para desenvolver o quadro de propostas, foram primeiro realizadas entrevistas com quadros superiores e intermédios da empresa e os dados de feedback das entrevistas foram utilizados para verificar a coerência com as perguntas pré-determinadas pelos autores como base para o quadro de propostas.

Os autores utilizaram a recolha de dados de questionários "*online*" para verificar a viabilidade da aplicação do quadro proposto. O processo baseou-se em seis dimensões de compreensão, racionalidade, validade, aceitabilidade, implementabilidade e apoio ao quadro proposto, tendo a maioria dos inquiridos concordado com a viabilidade do quadro. Foi também recomendado que o quadro fosse implementado com o empenho dos gestores de projecto e que fosse desenvolvido um guia explicativo do conhecimento Lean para melhorar a eficiência da implementação.

Os resultados sugerem que o quadro proposto é viável e pode ser implementado na próxima etapa da investigação-acção. O quadro oferece uma nova abordagem para tratar de questões de desenvolvimento organizacional.

Palavras-Chave: Investigação-acção, coisa magraReino, Quadro proposto, BIM, Aprovisionamento, Gestão de materiais

JEL Classification: M19, Y40

Contents

Figures Index

Graphs Index

Tables Index

Formulas Index

Glossary of Acronyms

·AR — Action Research
·BIM — Building Information Modeling
·BPM — Business Process Management
·CBRE — CBRE Group, Inc.
·CEO — Chief Executive Officer
·CF — Continuous Flow
·COO — Chief Operating Officer
·CRH — CRH Group Services Limited
· (CP) M — (Centralization Procurement) Management
· (DP) M — (Direct Procurement) Management
·E-Procurement — Electronic Procurement
·FIFO — First In, First Out
·JIT — Just-In-Time
·JITP — Just-In-Time Procurement
·LCM — Lean Construction Management
· (LP) M — (Lean Procurement) Management
·LPS — Last Planner System
·LPT — Lean Procurement Tools
·MEP — Mechanical, Electrical & Plumbing
·MOHURD — Ministry of Housing and Urban-Rural Development
·MOST — Ministry of Science and Technology of the People's Republic of China
·PDCA — Plan Do Check Act
·RCA — Root cause analysis
·RFP — Request for Proposal
·SOP — Standard Operation Procedure
·TIM — Total Innovation Management
·TOC — Theory of Constrain
·TPS — Toyota Production System
·TQM — Total Quality Management
·VSM — Value Stream Mapping

CHAPTER ONE INTRODUCTION

1.1 Overview

1.1.1 Challenges Facing the Project Construction Industry Worldwide

Generally, the international market distribution pattern is like the shape of a pyramid among them, well-known multinational construction contractors from developed countries have obvious competitive advantages and form monopolies in technology- and capital-intensive high-end projects. Construction enterprises from developing and newly industrialized countries can only participate in labor-intensive and highly competitive market international construction projects (Sihan Industrial Research Institute, 2022). In order to become more competitive, cross-border merger activities are increasing, international construction markets are becoming more concentrated, and competition at the top of the pyramid is becoming more intense. This trend poses new challenges for construction companies in developing countries (Chen, 2022).

The world political and economic environment has become more severe and complex, with global inflation intensifying, economic growth falling sharply, geopolitical conflicts heating up, and factors of instability and uncertainty increasing significantly. Globally, the construction industry faces huge challenges due to inflation, the main one of which is the rising cost of construction.

In its latest 2022 U.S. Construction Cost Trends report, CBRE mentioned that the construction industry has seen the largest increase in price levels in years due to labor shortages, inflation, supply chain disruptions, and the war in Ukraine (CBRE RESEARCH, 2022).

Albert Manifold, chief operating officer (COO) of CRH Ireland, one of the giants of the international building materials industry, believes that the construction industry will face the challenge of rising costs because rising energy prices are driving up all costs, from wages to logistics. This view is echoed by Rob Perrins, CEO of Berkeley, a well-known British property company, who said that his company's construction projects in London had to be significantly curtailed due to global inflation (Hailey, 2022).

Overall, the contradiction between rising costs and the development of the construction industry is becoming more and more prominent, and the challenges faced by the construction industry will continue to intensify.

1.1.2 Challenges Facing the Project Construction Industry in China

As a pillar industry of the national economy, the construction industry has been a major force driving economic growth during China's four decades of economic development.In recent

years, along with the decline in economic growth, the overall growth rate of the construction industry has also slowed down, and the profit margin (the ratio of total profit to total output value) of the construction industry output value has generally been on a downward trend since reaching a peak of 3.63% in 2014. In today's new form, the construction industry is facing great challenges (Helpful flow, 2022).

The trend of the construction industry is closely related to the macroeconomic trend, and still relies heavily on the scale of fast-growing fixed asset investment. The domestic construction industry will face huge challenges when the economic growth momentum no longer relies entirely on fixed asset investment. Since 2020, the development of real estate enterprises has encountered difficulties, the construction industry has also been dragged down, and the whole industry has been under tremendous pressure. How do enterprises transform? Where to break out? Where to change track? These have become the most important strategic choices faced by the head enterprises (Wang, 2023).

Influenced by the policy of "carbon peak" and "carbon neutral", the construction industry should not only save resources and reduce waste to achieve the goal of double carbon, but also increase the use of Building Information Modeling (BIM), smart site and other construction technologies and new materials, new equipment and new technologies in construction projects.

The traditional construction industry has a rough development model, backward management methods and production methods are not fine and the low concentration of the industry leads to overcapacity, which continues to squeeze the profit margin of the upstream and downstream construction industry, resulting in high construction costs and long-term low profits.

The rising cost of high-quality supply chain resources and rising factor costs have gradually become the main factors limiting the healthy development of the construction industry, putting the management of various aspects such as resource element procurement and construction costs of building construction enterprises to a severe test.

1.2 Research Problem

1.2.1 Company Background

The company the author works for is a building construction company. The company has more than 4,000 managers and 75 projects under implementation. Its main business scope is engineering and construction activities in the field of public buildings and infrastructure, including business types such as stadiums, conference centers, art centers, airport terminals, underground spaces, medical industrial parks, and energy stations.

With the development of China's economy, the era of rapid growth in the construction industry has passed and the industry is accelerating its fragmentation. Although the company

has experienced 25 years of rapid development and made many breakthroughs, however, in the face of the increasingly complex competitive market environment, problems in project procurement and on-site material management are becoming more and more prominent.

In the face of all these challenges, the company lacks more advanced management processes, management methods and lean concepts. There are many deficiencies in lean aspects such as cost management, innovation capability, industrial chain construction and corporate governance, which seriously threaten the quality of development and survival of the company. For example, the project procurement management is sloppy and does not give full play to the market competition mechanism: low procurement efficiency, insufficient procurement cost reduction rate; project lean management awareness is not strong, cost management ability varies, and the project's ability to open source and cut costs is weak; material management, serious waste, resulting in ineffective costs running at a high level. In order to cope with the fierce market competition, it is urgent to strengthen cost management and accelerate the transformation and upgrading.

1.2.2 Case Study

This case study examines the challenges faced by the company's project department in procurement and on-site materials management. By reviewing existing research and literature related to this study, we collected and sorted out knowledge and information related to lean management, lean techniques and tools, BIM technology, methodologies, process frameworks, etc., and developed a management model with lean concepts to form a systematic solution to help the project improve procurement and material management issues. The main steps are:

-Preliminary problem identification. Explore the reasons behind the problems through interviews with middle and senior management of the company to understand the practical application of lean concepts in project management.

-Data analysis of the interviews to develop models of lean management experience in procurement and materials management.

-Verify the validity of the developed model by distributing a questionnaire to project department managers and develop a set of proven recommendations or guidelines that can be followed by other projects in the company.

1.3 Research Questions

This study focuses on the company's key contradictions in cost management and identifies the key factors that constrain project procurement and site materials management performance, focusing on three issues.

Q1: What lean behaviors should be implemented in design management to improve

project procurement and materials management performance?

Q2: What Lean behaviors should be implemented in procurement management to further improve project procurement effectiveness and efficiency?

Q3: What Lean behaviors should be implemented in materials management again to effectively reduce waste in on-site materials management?

1.4 Thesis Objectives

This study will take the project management of construction enterprises as an example, focusing on the sloppy behaviors in project procurement and on-site material and machinery management, identifying the main reasons that restrict benefit acquisition, finding countermeasures, and forming a guiding management program to help projects apply a more lean management approach in future procurement and on-site material management to obtain greater benefits, gradually reduce procurement costs and process ineffective costs, optimize management process, promote the continuous improvement of project lean management, improve the cost operation management ability of the whole project cycle, and enhance the market competitiveness of the enterprise.

1.5 Thesis Contributions

The contribution made by this thesis research is mainly to form new summaries and recommendations through in-depth research and analysis, which can help the company to improve the project procurement management methods or management mechanisms, reduce the benefit loss in the procurement management process, and help the company to obtain new paths of efficiency creation in the procurement process. Meanwhile, providing a new research method for building construction enterprises to solve the organizational development problems of the industry.

Guiding more building construction companies surviving in the cracks to pay attention to construction drawing budget management and provide more accurate cost management targets for full-cycle lean management.

To establish a process management mechanism for reducing waste and transportation costs after the materials enter the construction site, so as to provide reference and guidance for more traditional construction companies, in order to promote and positively influence the lean procurement management or lean site management of construction companies, and gradually lead the construction industry to get rid of the rough and backward traditional management methods and enter the lean management stage.

1.6 Motivation

The author of the paper and the research team serve a building construction company. Based on the requirements of the author and the research team's position and the company's need for high-quality operations, the paper focuses on the company's current outstanding contradictions in procurement and materials management and cost management, and finds ways to improve efficiency and reduce waste. (Through research and big data analysis, the project research team broke down barriers to lean management in procurement management and on-site materials management, established new management ideas, filled in missing management actions, optimized management processes, refined management actions, and expanded management benefits.)

For this reason, by reviewing papers or scientific literature on lean project management, cost reduction, lean management, procurement management, materials management, and other related aspects, we cut through the academic and practical perspectives to dig into the root causes of the problems of enterprises in project procurement and on-site materials management. Through case studies and data analysis, we explore a more beneficial management method or management process to improve the quality of business operation and development, and help companies have more resilience in the market competition to deal with more competitive market risks.

1.7 Thesis Structure

This thesis will be presented in a sequential manner according to the following structure: first, the "Introduction", which introduces the background of the thesis in a short space and provides the scientific basis for this study through a "literature review". This is followed by an explanation of the "methodology" chosen for this study, followed by the "proposed framework". This is followed by "Data Analysis", which analyzes and interprets the questionnaire data of this study, and finally concludes with "Conclusion and Recommendations", "References", and "Appendix" to conclude this study.

CHAPTER TWO LITERATURE REVIEW

2.1 Introduction

In order to establish a sound academic foundation to support this research, a collection of domestic and international literature related to the dissertation topic was opened and an in-depth reading was conducted.

This chapter introduces the concept of Lean Management, Lean procurement, Centralization procurement, Direct Procurement, Materials Management, Important Aspects Affecting Materials Management Link, BIM and Action Research knowledge.

2.2 Theoretical Framework

2.2.1 Lean Construction Management (LCM)

Womack et al. (1992) mentioned the concept of lean is that it evolved from the Toyota Production System (TPS) in Japan. The concept was originally designed for the manufacturing industry but did not benefit the construction industry because it was the result of like-for-like production rather than mass production in manufacturing.

Koskela (1992) introduced the adaptation of the lean production concept in the construction industry and defined lean production as an approach to the design of production systems in which the production concept is presented as a production theory with three complementary approaches, namely (1) transformation; (2) flow; and (3) value creation. This perspective has driven the emergence of lean construction, a discipline that encompasses transformation-led contemporary construction management (Koskela et al., 2002; Bertelsen & Koskela, 2002). Lean construction management includes: (1) has a clear set of goals for the delivery process; (2) maximizes performance at the project management level for the client; (3) designs products and processes simultaneously; and (4) applies production control over the full project life cycle.

The principles and goals of Lean Construction are very similar to Lean Manufacturing, a project delivery process that aims to create production systems that reduce waste of time, materials and effort and create maximum value for the client. This is achieved by including all stakeholders and participants early in the project, such as architects, engineers, contractors, construction managers, and clients. This differs from traditional project management approaches where participants react to the design rather than influence it.

Dr. Tariq S. Abdelhamid of Michigan State University once said that lean construction draws on the principles of project management and production management, and that any successful project will involve an interaction between project and production management

(Banna, 2017).

Lean management is an extension of lean production theory and is an in-depth application of lean thinking at all levels of the enterprise. Nyambura et al. (2018) mentioned that lean management (LM) is a management model guided by lean thinking that identifies and eliminates waste through continuous product improvement to create more value for customers at a lower cost (Paul, 2012).

Waste is any inefficient behavior that results in the use of more equipment, materials, labor, or resources than are required for the production activity. Kendall (2021) mentioned that lean construction is accomplished primarily by eliminating waste, where the eight main types of waste in the construction industry are:

·Defects. Refers to anything that was not done right the first time, resulting in rework. Wasted time, materials and labor to correct the work.

·Overproduction. This type of waste occurs when a task is completed faster than expected or before the next task is ready to begin.

·Waiting. Workers keep waiting for materials to be delivered or for the previous job to be completed, disrupting the workflow and causing workers to wait for work.

·Transportation. Multiple moves of materials and equipment from one location to another, and these mobile efforts add no value.

·Inventory. In lean construction, move toward "just-in-time" inventory rather than "in-place" inventory.

·Motion. This is any unnecessary movement that can be eliminated, such as having to make multiple trips to the job site to get more tools or materials.

·Excess Machining. Excess processing is usually created when too much other waste needs to be dealt with, such as defects or inventory. Repeating inspections or adding additional processes to eliminate waste in other areas leads to more waste from overprocessing.

·Not utilizing talent. There is a mismatch between manpower and job requirements, which is a waste of human talent, skills and knowledge.

2.2.2 Theory of Constraints (TOC)

Goldratt (1986) introduced the theory of constraints (TOC), which is a management philosophy. The theory is a method of finding a constraint that limits the achievement of a goal and then systematically addressing that constraint until it is no longer a constraint. In the context of manufacturing, this constraint is referred to as a bottleneck. This theory emphasizes lean thinking and it will help to reduce waste.

Lean thinking defines value from the customer's point of view, so its key objective is to eliminate non-value-added activities throughout the enterprise and the costs they involve. By

identifying constraints, there is a positive impact on the time it takes for product manufacturing or service activities to flow through the system. When constraints are improved, variation is reduced and quality increases (Lysons & Farrington, 2006).

In project management, Theory of Constraints (TOC) is a problem-solving approach that helps you identify the most important bottlenecks or constraints that are hindering your project goals and objectives. For example, your material order is sent to the supplier and the material is late in arriving at the agreed upon point in time; your field work order is sent out and the field construction unit is not completed as you expected, and so on and so forth, there are many problems that are constrained by resources in terms of scope, time and cost. By identifying the "current bottleneck" enables a manager to focus concentrate on finding the solutions to improve capacity of that key resource that limits the performance in a firm.

2.2.3 Lean Procurement Management (LPM)

Zhong et al. (2015) proposed that lean procurement (LP) is the implementation of "lean thinking" in the process of procurement to eliminate waste and uncertainty in the procurement process and maximize customer satisfaction, which is essentially on-demand procurement, JIT procurement, waste avoidance and cost reduction.

Zhong et al. (2015) also suggested that the variability of the process affects the implementation of LP. Wang (2006) also argues that the procurement business process should be transformed from a traditional to a modern approach. To identify and reduce this variability, it is important to focus on the management of several important aspects:

·Materials management. Different procurement strategies are adopted according to the quantity of materials purchased, the cycle time, and the ease of acquisition.

·Supplier management. We adopt the "performance management" method and regularly check and evaluate to ensure the stability of cooperation.

·TPL control (Third Party Logistics). Through TPL's advanced logistics management system and developed network information system, we can reduce procurement costs.

2.2.4 Centralization Procurement Management (CPM)

Wen (2022) mentioned that centralized procurement management (CPM) is the centralization of goods, works, and services together for procurement management. The advantages of centralized procurement (CP) are reflected in supply chain management, centralized demand, reduction of procurement quantity, and reduction of procurement price. The material supply of construction enterprises is characterized by many varieties, categories and specifications, and the advantages of centralized quantity are conducive to the formation of scale transportation and reduction of raw material procurement costs (Meng, 2022; Yang, 2022).

According to Wen (2022), it is necessary to establish a unified management and hierarchical management model, improve the procurement system, robust the supplier resource information base, and build a special procurement agency and regulatory mechanism to ensure a scientific and reasonable implementation of CPM.

Yang (2022) focuses on the CP case for benefit analysis, while she mentions with concern that if CP is implemented, enterprises cannot make timely payments, or even often late payments, etc., which will certainly affect the subsequent supply of materials.

Wen (2022) and other authors elaborate on the procurement management system, procurement process, management system and supervision mechanism, which improves the top-level design of centralized procurement of bulk materials. It is a good guidance for the building construction industry.

2.2.5 Direct Procurement Management (DPM)

Tong and Lv (2014) mentioned that direct procurement (DP) refers to the way that the purchasing body purchases directly from the manufacturer without going through intermediate agents. DP shortens the supply chain, reduces procurement costs, improves the quality of procurement, and also effectively avoids the integrity risks of procurement personnel.

Hou (2021) presented the DP of steel and cement for a railroad project. Compared with the market price, the savings of steel reached 3.2%-5.15 and cement reached 6.5% by direct procurement. The economic benefits of DP are obvious from the data.

Wang (2014) mentioned that DP is an objective need to reduce procurement costs and improve procurement efficiency, so it is necessary to establish rules and regulations to control the source of demand planning, smooth the optimal procurement channels, and regulate procurement behavior. At the same time, it is necessary to establish strategic partnerships with manufacturers to help better implement the DP strategy.

Tong and Lv (2014) verified from case and data analysis the positive effects of direct procurement methods on the cost, quality, efficiency and service aspects of enterprise procurement, and generated high economic benefits, which have strong implications and guidance for changing traditional procurement methods.

2.2.6 Lean Procurement Tools (LPT)

Osodo and Onjure (2019) studied the application of lean procurement tools (LPT) in public institutions, which sought to determine the impact of JIT procurement, electronic procurement (EP), supplier relationship management and continuous improvement on the performance of the procurement function.

The study uses demographic and descriptive statistics as well as inferential analysis, and

these authors conclude that improvements in JIT procurement, EP, supplier relationship management, and continuous improvement will help improve the performance of the procurement function.

Finally, this study makes recommendations for process improvements to achieve zero inventory, zero lead time, e-tendering, supplier development, and reduced variability, which provide insight into the application and management of lean purchasing tools.

2.2.7 The Importance of Material Management

Napoleon et al. (2018) suggested that materials are a very critical factor in construction projects and good materials management can contribute significantly to project effectiveness, this is because materials cost accounts for 60-70% of the total project cost.

According to Oseghale et al. (2021), material costs account for 55-60% of project costs. Therefore, material management at the construction site is very important for the success of the project and efforts should be made to reduce material costs (Kulkarni et al., 2017).

2.2.8 Material Management

Shet and Narwade (2016) mentioned that cost, quality and time are important objectives of materials management and that purchasing materials in advance or delaying them can affect cost, quality and time.

Ayegba (2013) explained that materials management is a management process that coordinates materials planning, assessing needs, procurement materials, issuing and storing materials, and transshipment to minimize waste, which can reduce material costs and improve profitability.

Patel et al. (2015) stated that materials management is about obtaining the right quality and the right quantity of construction materials at a reasonable cost. Therefore it becomes important to get the right quality of materials at the right cost, at the right time.

2.2.9 Important Fators Affecting Materials Management

Arijeloye and Akinradewo (2016) discussed the problems of materials management and the methods of project materials management. According to Rahima and Vipin (2019), materials management is divided into five management phases: planning, supplier analysis, procurement, storage and inventory, supply and distribution. Factors affecting materials management were identified through a questionnaire:

Table 2. 1: Factors Affecting Material Management in Each Phase

No.	Phase	Factors
1	Planning	Poorly defined roles and responsibilities were the main problem, followed by warehouse distance and layout.
2	Supplier Analysis	Inadequate communication between contractors and vendors was the main issue.
3	Procurement	Causing delays and unavailability of materials was the main problem.
4	Storage and Inventory	Lack of modern equipment and handling methods were the main problems.
5	Supply and Distribution	Material damage and lack of material control are major problems.

Source: Author, 2023

For better understanding, the following aspects are briefly described:

·Materials Planning

The materials planning process includes documentation, inventory levels, and delivery frequency (Ademeso & Windapo, 2008). During the planning phase, the contractor must check the drawings for descriptions and explanations of materials, specifying the dimensions and specifications of the materials required, the quantity of materials, the quality requirements of the materials, the construction quality requirements, the distribution of materials in various parts, the purchase and delivery of materials, and the way of communication with suppliers, among other elements.

·Materials Estimation

Haddad (2015) mentions that benchmarking processes and techniques can be used to: set standards for waste control of building materials; estimate the amount of material required from the first drawing or final drawing; obtain the actual consumption of the material from field records or accounting records.

·Logistics

According to Yang et al. (2003), material transportation is one of the most important factors affecting project cost and time. Therefore, in order to manage materials effectively, it is necessary to predict the optimal material transportation and to plan access routes at the construction site.

·Materials Deviation Analysis

Material deviation analysis is a comparison between the actual amount of material used, the amount drawn and the amount that should be consumed. It is a management method to track and check the changes in material cost, quantity and waste during the project management process (Patel & Vyas, 2011).

2.2.10 Building Information Modeling (BIM)

2.2.10.1 BIM's Definition

BIM is a digital representation of the physical and functional characteristics of a building equipment facility (construction project). It is a repository of shared information about a

building's equipment and facilities, a process that provides a reliable basis for all decisions throughout the life cycle of that facility, from conception to demolition (National Institute of Building Sciences, 2014).

BIM is the virtual presentation of equipment and facility information and serves as a shared information resource for facility information that can help projects make the right decisions at different stages (Sacks et al., 2018).

The core functions of BIM are (1) support for process collaboration among multiple teams; (2) creation of realistic virtual reality scenarios; (3) generation of three-dimensional (3D) models based on intelligent data; (4) sharing and merging intelligent model data with designers, construction management professionals, and facility managers; (5) project schedule (4D) and cost (5D) simulations; (6) support for different feature simulations (e.g., energy efficiency simulations); (7) model-based online communication; (8) data sharing with digital manufacturing systems; (9) maintaining information and design model integrity; (10) automated documentation; and (11) using model data for different analyses (e.g., automated material quantities) (Sacks et al., 2010).

2.2.10.2 BIM's Development in China

In 2001, China began to explore information construction. In 2010 the MOHURD announced that BIM was listed as one of the "Top Ten New Technologies in the Construction Industry" as a key application technology of informatization (Ministry of Construction, 2018).

The MOST has clearly listed BIM technology as a national key research and application project in the "12th Five-Year Plan" for science and technology development. Therefore, 2011 is called "the first year of BIM in China" (Ministry of Science and Technology of the People's Republic of China, 2018).

2.2.10.3 BIM in Construction Management

During the design phase of the MEP drawings, BIM performs collision detection by enabling "clash detection" to determine where piping crosses, meaning the model visualizes to the team which parts of the building may cross incorrectly (e.g. between the building structure and ducts, pipes), eliminating in advance collisions that may cause rework and demolition (avoids waste).

Using BIM technology, a virtual construction rollout of the facility can be performed prior to actual construction to simulate and analyze potential influencing factors during construction, enhancing the controllability of the construction process and improving safety. Each subcontractor can input key information into the BIM model prior to construction and can prefabricate or pre-install some facilities or piping off site. Such an approach minimizes on-site material waste and products can be delivered in a timely manner rather than stored in on-site

warehouses (Smith, 2007).

BIM technology can effectively extract material quantities and common attributes, facilitate accurate estimation of materials needed in drawings, and effectively manage waste due to over-procurement.

2.2.11 Action Research (AR)

2.2.11.1 AR's Definition

Action research is a research philosophy and methodology that is broadly applicable to the social sciences. It seeks change through the simultaneous conduct of action and research, and by linking the two through critical reflection.

The term "action research" was first coined by Kurt Lewin. He explained action research as "the comparative study of the conditions and effects of various forms of social action and the research that leads to social action" (Lewin, 1946).

2.2.11.2 AR in Organization Development

According to French and Bell (1975), Organizational Development (OD) is the improvement of an organization through action research and argues that the idea of action research as proposed by Kurt Lewin encapsulates the basic philosophy of OD.

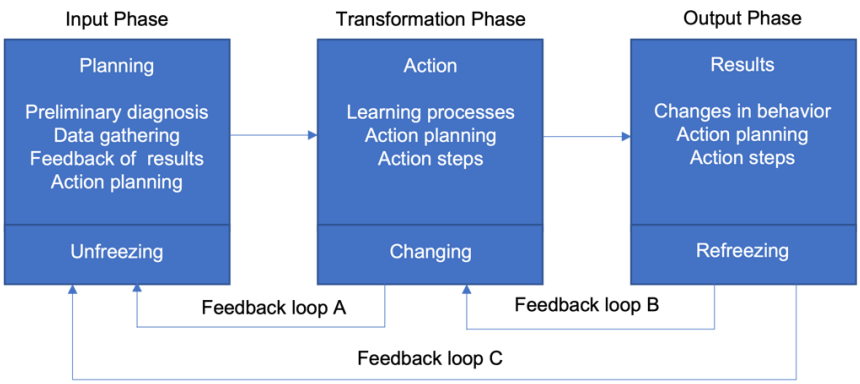
Lewin is particularly concerned with effective and lasting social change and believes that the dynamics of change are closely linked to action. If people are actively involved in decisions that affect them, they are more likely to adopt new approaches. He saw rational social management as proceeding in spiraling steps, each of which is a cycle of planning, action, and fact-finding about the results of that action (Lewin, 1958).

Unfreezing: the first step.

Changing: Diagnose the situation, explore and test new patterns of behavior.

Refreezing: Evaluate the application of the new behavior, and if reinforcing, adopted.

Figure 2. 1: System Model of Action-Research Process



Source: Lewin, Kurt (1958)

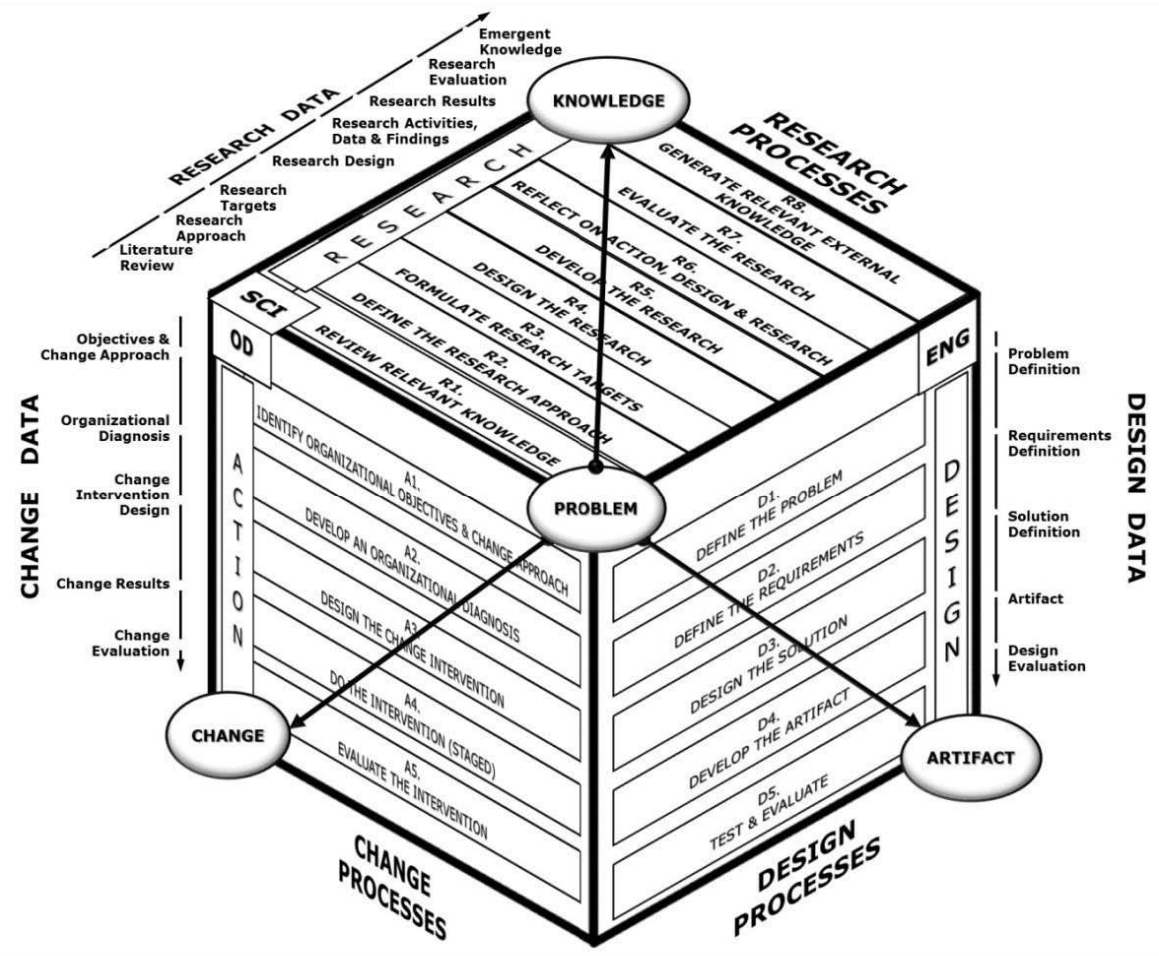
2.2.11.3 AR Process

Regarding the steps of action research, Henriques and O'Neill (2020) cited relevant literature in the field of AR research to describe the evolution of the steps of AR research. The widely accepted AR model was introduced, where AR is considered as a cyclical process with seven main steps: diagnosis, action plan, action, evaluation, concrete learning (Susman & Evered, 1978), observation and reflection (Kemmis & McTaggart, 1990).

Coghlan and Brannick (2014) sorted out the key elements in action research at a logical level. A set of questions typical of initial research is proposed, such as, "What is action?" "What is the current situation?" "What is the plan to get from here to there?" "What is the timeline," "Who are you working with," "How do you plan to explore the action?" And so on.

Based on empirical results from an organizational change project, Henriques and O'Neill (2018B) published a three-dimensional conceptual model (See Figure 2.2 Below) that very visually illustrates each step of the action design research process, providing a powerful spatial conceptual guide for efficiently solving organizational change problems.

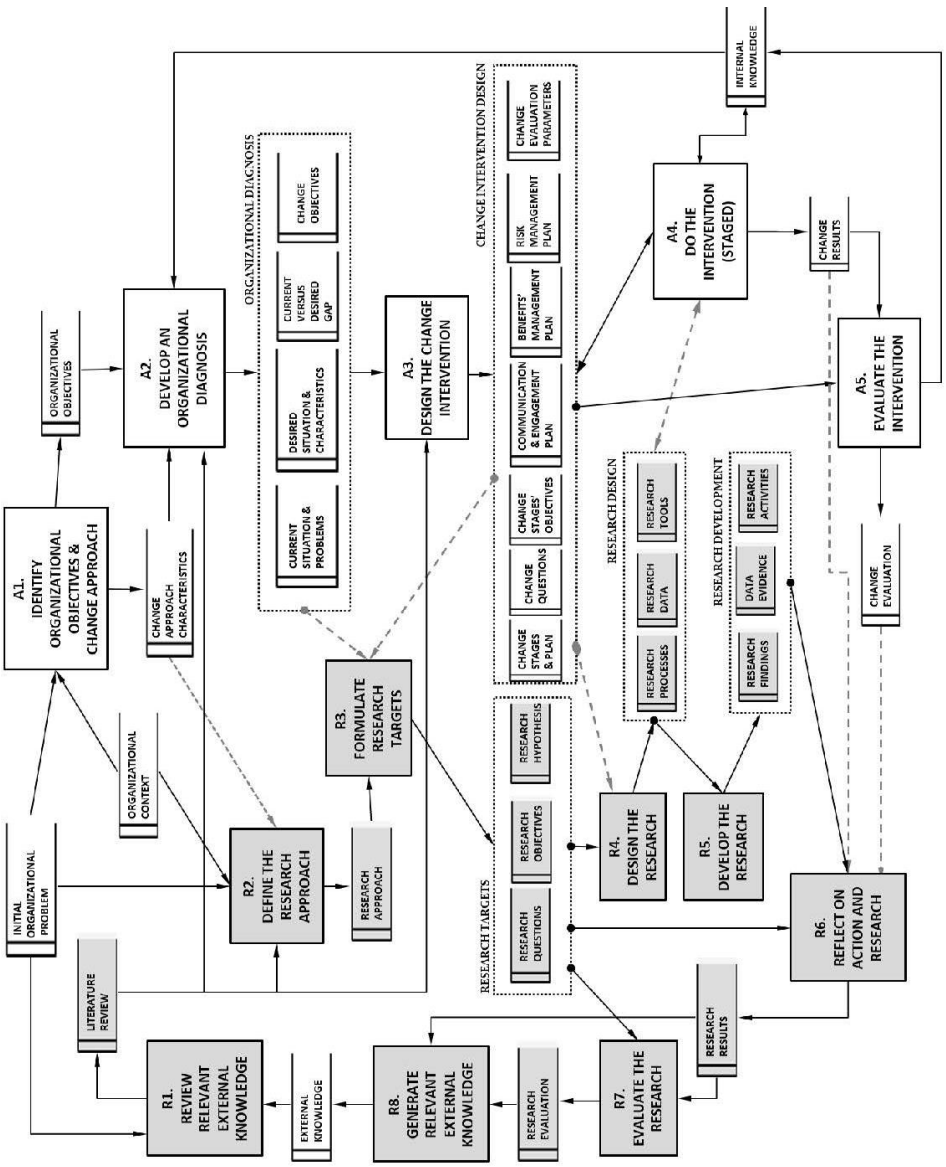
Figure 2. 2: ADR Foundations: the Science, OD, and Engineering Perspectives



Source: Henriques & O'Neill, (2018B)

Based on previous research findings, Henriques and O'Neill (2020) published another process model of action research, which is presented in a two-dimensional form, and this graphic depicts the logical relationships between each step of action research, providing a clear roadmap for this study (See Figure 2.3 Below).

Figure 2. 3: Action Research – a Process Meta-Model



Source: Henriques & O'Neill (2020)

2.2.12 Process Classification Framework (PCF)

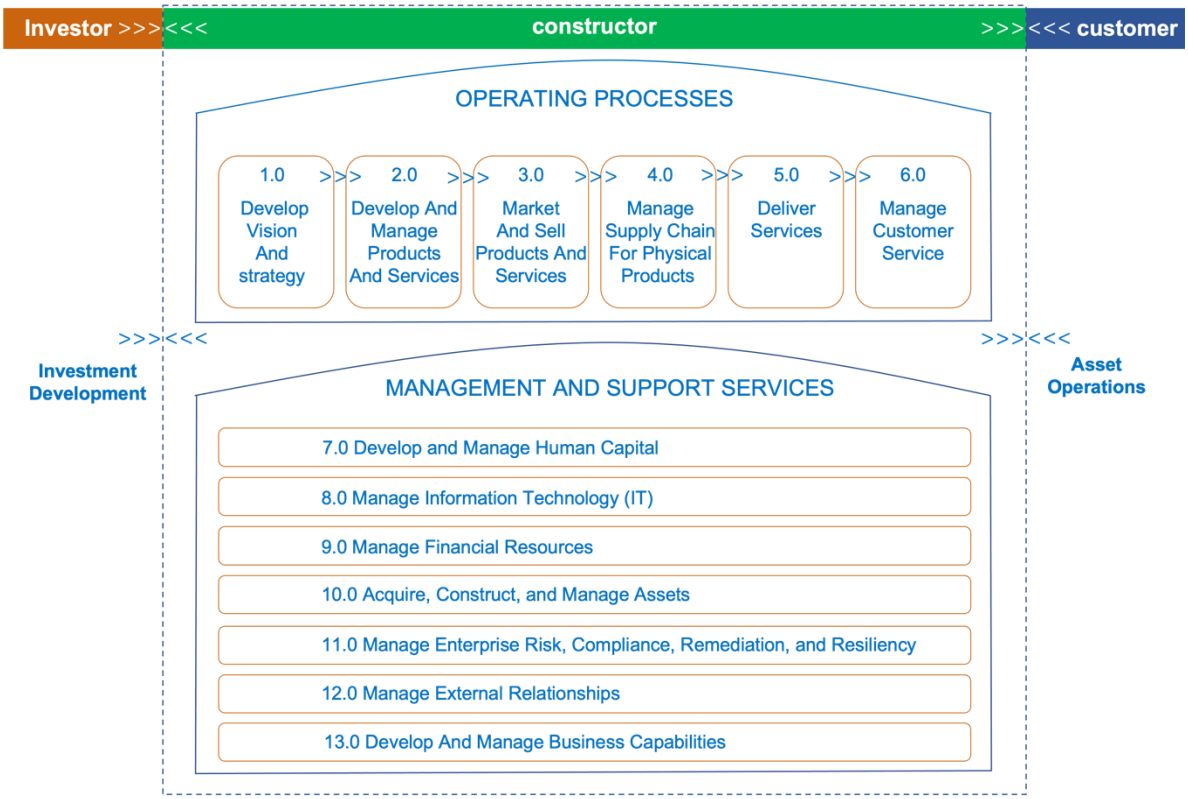
The cross-industry Process Classification Framework (PCF) is a cross-functional business process taxonomy whose primary purpose is to provide an objective comparison of performance within and across organizations.

The PCF was developed by APQC and its member organizations as an open process benchmark to promote organizational improvement primarily through process management

and benchmarking, which is not limited by industry, size or location.

The PCF organizes operational processes, management and service processes into 13 enterprise-level categories, which also include process groups and more than 1,000 processes and related activities (APQC, 2022).

Figure 2. 4: Cross Industry PCF (Version 7.3.0)



Source: APQC (American Productivity & Quality Center)

According to Damayanti et al. (2019), in order to achieve an organization's intended goals, an effective approach is to adopt clean processes, identify redundant processes, eliminate ineffective activities, and continuously improve the performance of supply chain management. The key to lean management is to achieve work processes that enable employees to continually improve productivity and reduce project costs. This study aims to effectively address and improve the problems in project procurement and on-site materials management, and therefore requires the identification of ineffective processes in project procurement and materials management, and the need to benchmark advanced benchmarking processes to help quickly identify waste and achieve continuous improvement.

APQC's cross-industry PCF Process Framework is an internationally recognized process and performance improvement resource that serves as a benchmark to which the construction industry can refer for implementation. The framework enables building construction companies to improve project management performance through the implementation of lean management practices. Specifically, the framework is applied to management practices through the use of a business process management (BPM) approach, the use of APQC's PCF as a mechanism

to support process improvement, and the use of an action-design-research approach to managing change within a company. It promotes continuous improvement of lean management and business processes. It also enables the extension of lean practices to other business processes managed within the company.

CHAPTER THREE METHODOLOGY

3.1 Introduction

This chapter describes the research framework used in this study. Thus, the research methodology, action plan, study population, sample size determination, data collection instruments, methods and techniques for analyzing the data are specifically described. The design of the interviews and questionnaires were also examined.

3.2 Research Framework

3.2.1 Research Approach

This study adopts an action research approach with the aim of developing a conceptual framework based on a proposal that integrates BIM and lean thinking to provide solutions to waste in purchasing and site materials management and to promote continuous improvement in organizational management. The literature review suggests that a distinct advantage of action research over other theories is that it provides an opportunity to explore the waste problems that exist in the lean management process and to address them in a specific way.

AR has proven to be an effective tool for learning and development and is a widely used methodology in organizational change and development processes to facilitate the realization of the researcher's ideas and aspirations. The task of action research is to test hypotheses and achieve some (assumed) desired change. It has two parallel action research cycles, a core action research cycle and a dissertation action research cycle, with the goals of: (1) solving problems and; (2) making a contribution to science. (Henriques & O'Neill, 2020).

This study demonstrates only the first phase (unfreezing) of AR. The entire paper constitutes the entirety of this study, where the introduction section describes the problem and motivation, the literature review section discusses the BIM technology AR roadmap, followed by the development of the conceptual framework and the validation framework. (The changing phase and refreezing phase are out of the scope of this thesis).

3.2.2 Research Targets

A key requirement of action research is to be clear about the objectives of the study. Here, the research questions of this thesis are again recalled: Q1, Q2 and Q3, and the subsequent research aims to answer these questions (See 1.3 Research Questions).

3.2.2.1 Identifying Problems

The author has been working in the field of construction management for more than 10 years.

Based on the experience of actual workers, I speculate that the wasteful behavior in procurement and on-site material management may be caused by the following reasons:

Design Management Pain Points: (1) The design department does not play a guiding role in cost management; (2) Failure to establish standard specifications; (3) Not playing the role of BIM tools; and (4) ineffective communication.

Procurement Management Pain Points: (1) sloppy and inefficient procurement mode; (2) relatively low procurement efficiency and effectivity; (3) ineffective communication; and (4) integrity issues.

Material Management Pain Points: (1) unclear management objectives; (2) serious waste; (3) No supplier management and assessment; (4) lack of financial security; and (5) ineffective communication.

3.2.2.2 Preliminary Diagnosis

Identify the company's pain points in design, procurement, and materials management by talking to interviewers and verify the consistency of these pain points with the problems identified by the author (See 5.2.1 Initial Diagnostic Verification).

3.2.3 Solution Design

Based on the identified content of the proposal, the philosophical principles of Lean thinking will be introduced and the development of the proposed framework will be carried out using Lean tools and PCF business processes, which will be examined in detail in Chapter 4, Proposed Framework (See 4.5 Proposed Framework Development).

3.2.4 AR Implementation Planning

To improve the validity of AR, a 5-week research plan was developed to complete all data collection and analysis for the paper in May.

Table 3. 1: AR Implementation Planning (Unfreezing)

No.	Contents	May.				Jun.
		1st week	2nd week	3rd week	4th week	1st week
1	Preliminary Diagnosis	OK				
2	Data Collection (Pilot Interviews, Questionnaire)		OK			
3	Data Collection (Proposed Framework Validation)			OK		
4	Data Analysis	OK			OK	
5	Evaluation, Discussion and Summary					OK
6	Emergent Knowledge					OK

Source: Author, 2023

3.3 Research Population

The subjects of the study are the internal managers of the author's service company, mainly middle and senior management, related departments such as design and procurement, and front-line managers in the project department.

3.3.1 Management Layer

The target group for the interviews was mainly middle and senior management, design, purchasing, and engineering personnel, who are the developers and supervisors of the system management and system approach, and who are important participants in making decisions about the direction of the company. Salem et al. (2005) identified top management commitment to the implementation of a lean framework as an important factor influencing the successful implementation of the framework, and therefore the opinions of middle and senior management would contribute to this study.

Table 3. 2: Procurement and Material Management Department Function Introduction (Brief)

Department (Scope)	Responsibilities
Procurement Department (Initiating tenders — contract signing)	Construction and revision of procurement management system and standardized management manual, supervision, inspection and assessment management.
	Subcontracting, professional service materials, machinery and equipment procurement
	Sub-supply resource base, price and cost database, material and equipment brand library management
	CP, Joint Procurement, DP and single procurement bidding management, framework contract agreement drafting and contract signing
	Procurement planning and planning, compliance control, information operation and maintenance, business training
	Collaborative procurement management for the whole process of EPC projects
Material management Department (Contract Implementation—Settlement)	Construction and revision of material management system and standardized management manual, supervision, inspection and assessment management.
	Responsible for the acquisition and disposal of own assets and project assets, as well as the turnover management of other own working materials and temporary construction assets.
	Responsible for the management of total material demand plan, material order, material acceptance, material inventory and over analysis management, settlement audit and other related work
	Supplier and other resources development, introduction, cultivation, maintenance, management and evaluation.
	Payment management, information platform application management, big data management, compliance management and innovation management.
	System talent echelon construction, talent training and business training

Source: Author, 2023

3.3.2 Business Layer

The target groups of the questionnaire survey are project managers, design managers, material managers, procurement managers and material engineers. The main reason for choosing this group is that their main activities are on the front line of construction sites, and their daily work is directly or indirectly involved in design, procurement and material

management practices, and they can see the real situation of the problem and grasp a lot of basic data, which is very helpful for this study.

3.4 Sampling Techniques and Sampling Size

The sampling methods used to collect data are quota and purposive sampling techniques. To ensure that there is no bias or subjectivity in the sampling process, the selection of an appropriate formula is critical to determine the appropriate sample size.

Bixley and Yamane (1965) proposed a straightforward method to calculate the sample size based on maximum variability (p=0.5) and 95% confidence level (this formula is applicable when both the number and distribution of respondents are known, and the sampling situation in this study is consistent). The Yamane sampling formula is stated as follows:

Formula 3.1: The Yamane Taro sampling formula

$$n = N/[K + N(e)^2] \quad (3.1)$$

Where n = sample size;

N = population;

k = constant (1); and

e = degree of error.

A simple random sampling technique was used in this study, and a 95% confidence level, 0.5 variability and 5% precision were used in determining the required sample size.

The sampling frame for the questionnaire was the managers of 30 active projects at the authors' service company. The number of project managers, design managers, material managers, procurement managers, and material engineers in the projects under construction was 30, 30, 30, 20, and 30, respectively.

N=30+30+30+20+30=140, when “e” = 0.05

$$n = N/ [1 +N(e)^2]$$

$$n =140/ [1 +140(0.05)^2]$$

$$n =104$$

The Sample Size Was 104 People。

3.5 Data Collection Tools

Due to the scattered distribution of project departments of the author's service company, there are practical difficulties to visit and distribute questionnaires one by one. At the same time, the traditional paper questionnaire form, inefficient, in order to be more efficient and fast, so we through the questionnaire app - WeChat Questionnaire Star, to collect questionnaire data in an online way.

Distribute structured questionnaires linked to workgroups to collect data on what project

managers, design managers, materials managers, procurement managers and materials engineers know about design, procurement and materials management practices.

3.5.1 Pilot Study

To ensure the reliability of the assessment questionnaire, a pilot study was conducted in which the questionnaire was distributed to materials engineers on five different projects to fill out.

The purpose was to find out whether the questions in the questionnaire were easy to understand, to minimize understanding bias, to help collect more realistic answers, and to facilitate a smooth study.

3.5.2 Interviews

In order to fully validate the initial diagnostic and proposed framework of this study, interviews were conducted with the company's middle and senior leaders, each lasting approximately 20 minutes, conducted face-to-face, or completed via Tencent Meeting.

The interview script consisted of six questions, with questions 1-2 used to characterize the sample, question 3 used to validate the initial diagnosis, and questions 4-6 used to assess the familiarity of senior and middle managers with Lean knowledge and the actual implementation of Lean management (See Appendix A).

3.5.3 Questionnaire

A structured questionnaire was designed to collect primary data based on the information from the literature review, the preliminary diagnostic questions, and the proposed framework content.

The questionnaire consisted of 12 questions. Questions 1-2 were used to collect background information about the respondents. Questions 3-6 were used to assess the respondents' familiarity with Lean concepts and principles, the application of Lean methods in management, and the positive effects of Lean thinking, while questions 7-12 were used to verify the respondents' level of understanding of the proposed framework, its rationality, validity, acceptability, implementability, and managerial support (See Appendix C).

3.6 Data Analysis Method

The analysis of the questionnaire data in this study employed both quantitative and qualitative (mixed) research design strategies. Naoum (2007) argues that quantitative research is objective in nature and it is an investigation of a social problem based on testing the validity of recommendations or theories consisting of variables. Since this study seeks to test the validity of a number of proposed frameworks, a quantitative method of investigation using a structured

questionnaire is considered appropriate (Haddad, 2015).

The design of the qualitative analysis took the form of structured interviews and the use of open-ended questions to obtain detailed information about the respondents.

In this study, descriptive statistics were used to obtain feedback data through interviews and questionnaires, and excel was used to complete the data analysis. The final statistical analysis of the specific data was presented mainly through tables, bar charts and pie charts (See Chapter 5 on data analysis).

Kothari (2004) mentioned that descriptive survey data are mainly presented through means, standard deviations, frequencies, graphs, and pie charts. Data analysis is presented in graphical form for easy reading and understanding.

CHAPTER FOUR PROPOSED FRAMEWORK

4.1 Introduction

This chapter introduces several aspects of Lean thinking, Lean techniques, and Lean development. Undoubtedly, the principles of the Lean philosophy are the most fundamental principles that need to be followed when developing a proposal framework to achieve the objectives of the thesis. This paper will adopt the Business Process Management (BPM) methodology, benchmark the PCF process framework, and develop a multi-dimensional proposal framework with Lean philosophy, aiming to apply Lean thinking to project management practices and provide a systematic solution in the field of project procurement and on-site material management.

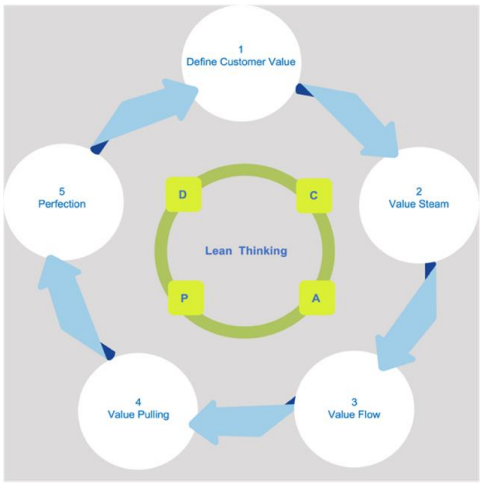
4.2 Lean Philosophical Thinking

The classic book Lean Thinking refers to five principles of the Lean methodology, which can be described as five steps: defining customer value, value streams, value streams, value pull, and perfectionv (Womack & Jones, 2003).

According to Fitzsimmons (2014), there are three guiding principles of lean thinking, which are: (1) Meet customer needs by performing only those activities that add value in the eyes of the customer. (2) Define "value streams" through process mapping to identify value-added and non-value-added activities. (3) Eliminate waste. Waste in the value stream is any activity that the customer is not willing to pay for. On the other hand, Howel and Ballard (1998) express the principles of lean thinking as (1) stopping the production line, (2) moving the product forward, (3) one-piece flow, (4) synchronization and alignment, and (5) transparency.

In summary, the core concept of Lean thinking is to eliminate waste and create value.

Figure 4. 1: Lean Thinking Cycle Flow Chart



Source: Author, 2023

4.2.1 Define Customer Value

The customer's point of view defines the entire process from design to production to delivery to achieve the maximum satisfaction of the customer's needs. The customer's view of value also requires minimizing excess consumption throughout the production process and not passing additional costs on to the customer.

4.2.2 Value Stream

This refers to the entire range of activities that transform raw materials into finished products and assign value to them. Such activities include the technical process from concept to design and engineering to production, the information process from order processing to planning to delivery, and the material transformation process from raw material to product, as well as the support and service process throughout the product life cycle. The book Lean Thinking by Womack and Jones (2003) divides activities in the value stream into three categories: activities that create value, activities that do not create value but have to be done under current technology conditions (Type I waste), and activities that do not create value and can be removed immediately (Type II waste).

4.2.3 Value Flow

"Flow" and "Pull" are the keys to realizing the value of Lean thinking. Lean treats all stagnation as corporate waste and calls on "all people to fight against departmentalized, mass-production thinking" and to create continuous flow of value under any mass production conditions using continuous improvement, JIT, and one-piece flow. Achieving continuous flow requires that every process and every product be correct.

5S and TPM are one of the prerequisites for value flow. Having the right size of manpower and equipment capacity to avoid blockage caused by bottlenecks. In addition, it is important to make good use of buffers to balance the impact of flow changes.

4.2.4 Value Pulling

"Pulling" is about inputting and outputting what the customer needs, so that the user gets exactly what they need, when they need it. Its more far-reaching meaning is to produce directly to the customer's actual needs, leaving behind forecasts.

The way to achieve pull is to implement JIT production and one-piece flow. Flow and pull will reduce product development time by 50%, lead time by 75%, and production cycle time by 90%.

4.2.5 Perfection

Miracles happen as a result of the interaction of the four principles mentioned above. The result through Kaizen is an accelerated value stream. This requires the continued use of value stream analysis to identify more hidden waste and continuous improvements through Kaizen. This virtuous cycle becomes a process of convergence to perfection.

Based on the above principles of Lean thinking, it is necessary to organize and integrate Lean techniques and tools into the management practices of the organization to identify and eliminate waste problems and to help the organization make continuous improvements.

4.3 Lean Techniques and Tools

Different Lean techniques and tools can identify and eliminate waste, with the ultimate goal of achieving the best quality, lowest cost and shortest delivery times.

Although automotive manufacturing and building construction are separate industries, Lean Construction and Lean Manufacturing (manufacturing) share the following ideals: (1) a focus on optimizing the entire system based on collaboration and intrinsic learning; (2) a belief that processes can always be improved to achieve perfection; (3) a recognition that everyone involved contributes the most value and; (4) a commitment to ensuring the flow of value by removing barriers and eliminating the parts of the process that do not add value to ensure that value flows.

There are many similarities between building construction and automotive manufacturing in the material procurement process. Lean construction methods are influenced by Lean Manufacturing and apply many Lean Manufacturing principles and Lean Manufacturing tools to Lean Construction. Any tool that can improve processes and add value can be used as a reference for application, which is why tools such as A3, Value Stream Mapping, 5S, Kanban, Kaizenevent, etc. can often be found in construction (Kendall, 2021).

Of course, given the similarities between lean manufacturing and lean construction, it is not surprising that construction industry practitioners turn to the same techniques that other lean practitioners use to capture improvement opportunities, manage improvement projects, and track lean progress.

Table 4. 1: Lean Techniques and Tools

Lean Techniques and Tools	Description	References
5S	it focuses on the effective management of production site elements, to achieve standardized management.	(Womack & Jones, 2003)
Andon	A visual management tool that transmits work orders or status through an electronic display.	ibidem
Just-in-time (JIT)	JIT means producing what the customer needs at the required time and in the required quantity.	ibidem
Kanban Systems	A tool for controlling a field production flow that helps implement a Pull system by transmitting information through Kanban.	ibidem
Kaizen Event	An approach to continuous improvement, people, and processes, usually in small, continuous steps over a sustained period of time.	ibidem
Root cause analysis (RCA)	An iterative technique for finding the root cause of a problem and solving it effectively through corrective action. (e.g., 5-Whys, Ishikawa Chart).	ibidem
Continuous Flow (CF)	Each step performs only the work necessary for the next step, effectively identifying and eliminating waste from inventory, waiting, and handling, which can be achieved through batch and queue.	ibidem
Pull Plan	Production according to customer needs, production plan only sent to the final (finished) process, the back process through the kanban to the front process to give orders to pull the front process.	ibidem
Value Stream Mapping (VSM)	A visual comparison of current and future production streams to find ways to improve can expose waste in current processes and map a roadmap for future improvement.	ibidem
Hoshin Kanri	A method of ensuring that a company's strategic goals drive implementation and action at every level, designed to eliminate waste due to inconsistent goals and poor communication.	ibidem
Toyota Production System (TPS)	The basic idea of TPS is to "completely eliminate waste" and to pursue low-cost, high-efficiency, high-quality product manufacturing through integrated production.	ibidem
Plan Do Check Act (PDCA)	PDCA is an iterative four-step management approach to controlling continuous process and product improvement.	ibidem
Poke Yoke (Error Proofing)	A method to achieve ultimate (customer side) zero defects by preventing and detecting defects.	ibidem
Total Quality Management (TQM)	TQM is a continuous improvement system, which takes product quality as the core and customer demand as the purpose of full participation management technology.	ibidem
A3 Report	A visual method for summarizing and explaining strategies, introducing projects and solving problems.	(Ko & Tsai, 2013)
Kamishibai Boards	A visual control tool that helps assign, prioritize, execute, and follow up key work procedures and tasks.	(Niederstadt, 2014)
Last Planner System (LPS)	LPS is a planning and management system for lean construction that measures and improves the reliability of the planning system through per plan completed rates (PPC).	(Maru, 2015)
Standard Operation Procedure (SOP)	SOP is a textual standard based on a scientific process and operating procedure based on value stream analysis.	(Fakhriah & Noordin, 2013)
Total Innovation Management (TIM)	A management model that constantly innovates, finds waste, and eliminates waste by motivating all employees.	(Iskoskov & Sosunova, 2013)
First In, First Out (FIFO)	A method of managing the sequence of material storage and transportation. The use of items follows the principle of first-in items first-out.	(Md Said & Radzuan, 2017)

Source: Author, 2023

4.4 Proposed Framework Development

Based on constraints in design, procurement and materials management (See Appendix B), this thesis incorporates Lean concepts and techniques (See Table 4.1 above) and uses the PCF business process framework as a benchmark (See Figure 2.4 above) to develop a Lean management framework, which was further validated through interviews and questionnaires

(See Appendix C).

Among the main PCF categories, groups and processes applied in the framework are: Project Design: (Category 2: Group 2.3, Process 2.3.1), Procurement Management (Category 4: Group 4.2, Process 4.2.1, 4.2.2, 4.2.3) and Materials Management (Category 4: Group 4.2, Process 4.2.3, 4.2.4, 4.2.5; Group 4.4, Process 4.4.3).

TOC theory is an approach to analyzing constraints and solving project management problems (See 2.2.2). The ideas in the theory provide insight into the need for continuous improvement to address constraints in organizations. The theory was used to test the following three business process areas.

4.4.1 Project Design Management

BIM and Lean are important innovations in the architecture and engineering industry, and the two are in a mutually supportive relationship. BIM has been used to generate and compare designs to ensure the best use of resources, reduce design time, improve collaboration between stakeholders, and reduce errors in design and construction, and is used to improve the productivity and efficiency of the industry (Rahman & Belayutham, 2022).

Past research provides strong evidence for the positive impact of the relationship between BIM and Lean on projects. BIM functionality and Lean principles can provide significant benefits to organizations even when implemented in isolation (Sacks et al., 2010a).

Theoretically, the relationship between BIM and Lean can be bidirectional, meaning that BIM can support Lean principles and, in turn, Lean can support the implementation of BIM (Bhatla & Leite, 2012).

When BIM impacts Lean (BIM → Lean direction), BIM can help Lean achieve waste elimination (regarding overproduction, rework, and wait time), reduce variability and cycle time, and visualize production methods and processes (Sacks et al., 2010). For example, BIM's "automatic rationing" feature can help generate accurate and reliable cost estimating information, free of errors, rework, and waiting, all of which Lean seeks.

"Standardization" is a lean principle that helps to identify the best methods to use in a process and to minimize variation (Feng & Ballard, 2008).

Therefore, a standardized system is necessary for the successful implementation of all the requirements of BIM.

BIM management is the most challenging area in terms of pain points, and the authors identified a set of initiatives based on lean principles to correct these pain points associated with the PCF process (See Table 4.2 Below).

4.4.2 Procurement Management

Due to the many challenges in procurement management such as wasted resources,

excessive costs and integrity, many organizations are looking to achieve efficiency and effectiveness in their supply chain management. To achieve this goal for organizations, it is a good approach to adopt a lean supply chain management process, which can help identify and eliminate ineffective activities in operations and promote performance improvement (Damayanti et al., 2019).

Data from the APQC Procurement Open Standards Benchmark shows that more than 25% of organizations have invested in developing lean processes for their procurement functions. In recent years, more and more organizations are planning to invest in developing lean processes. Organizations that embrace Lean initiatives must engage their employees in Lean management to ensure that these individuals understand the reasons for making the change and the potential benefits to the organization (Partida, 2014).

Osodo and Onjure (2019) mentions a case study of procurement in a public institution, where by using lean tools such as JIT and zero inventory, variability was reduced, many non-value added activities were reduced, and there were significant improvements and enhancements to the delivery time, cost and quality of procurement.

To address the pain points in procurement management, a series of initiatives (See Table 4.3 Below) were designed using Lean tools to continuously remove bottlenecks, especially to improve processes and optimize the entire process by eliminating bottlenecks in procurement efficiency and effectiveness and integrity.

4.4.3 Material Management

In the area of lean tools applications, there are many case studies that demonstrate that combining and utilizing good lean techniques and tools can increase productivity and reduce project waste. LPS reduces waste and rows by accelerating work processes, enhanced visualization can improve safety and reduce cost issues, and 5S tools can reduce waste and lower costs (Salem et al., 2014).

Koranda et al. (2012) claimed that combining sustainability with lean can reduce process and material waste, lower costs and lead times, reduce water use, reduce energy consumption, and improve environmental quality. Nahmens and Ikuma (2012) conducted a study that found that LC, by reducing material waste by 64% produced a considerable environmental effect; and a significant economic effect by reducing the production time by 31%.

This study focuses on the pain points in materials management, incorporates lean thinking to propose a series of measures, and develops a proposed framework because it is simple and efficient(See Table 4.4 Below).

Design Management Pain Points: (1) The design department does not play a guiding role in cost management; (2) Failure to establish standard specifications; (3) Not playing the role of BIM tools; and (4) ineffective communication.

Table 4. 2: Proposed Framework — Design

Lean Principles	Pain Points	Lean Techniques And Tools	PCF Process Benchmarking	Proposed Initiatives
Define Value	(1)	Hoshin Kanri	2.3.1 Assign resources to product/service project(10083)	Proactively identify value-creating needs in project procurement management, materials management and cost management, and implement BIM positive design.
Value Stream	(3)	VSM,LPS,Kanban	2.3.1.13 Identify design/development performance indicators(10091)	Define management objectives and develop a reasonable BIM design work schedule.
Value flow	(1) ,(4)	VSM,A3,SOP	1.2.5.6 Develop role analysis and activity diagrams for key processes (10054)	Clarify the BIM workflow and establish a transparent role division of responsibilities and authority.
Value flow	(2)	Poke Yoke, RCA.CF	2.3.1.4 Develop user experience design specifications (16813)	Establish technical specifications to provide technical guidelines for procurement department prepares RFPs.
Value flow	(4)	CF,PDCA,Kaize, RCA	1.2.5.3 Develop role activity diagrams to assess hand-off activity (10051)	Proactive communication with procurement and material management department to improve efficiency.
Value Pulling	(3)	JIT,Pull Plan	2.3.1.8.5 Design and manage product data, design, and bill of materials (16818)	According to the construction drawing budget requirements, BIM technology is used to integrate the material and equipment parameters into the drawings in advance and output the accurate material quantities.
Value Pulling	(1)	JIT,Pull Plan	2.3.1.6 Document design specifications (10086)	Establish a database of material and equipment parameters according to the needs of procurement tender management.
Perfection	(2),(3)	SOP,Kaizen,PDCA, Hoshin Kanri	2.3.1.3 Develop product/service design specifications (10085)	Strictly implement the BIM management system and standardization management, and regularly organize the revision of the standardization manual.

Source: Author, 2023

Procurement Management Pain Points: (1) sloppy and inefficient procurement mode; (2) relatively low procurement efficiency and effectivity; (3) ineffective communication; (4) integrity issues.

Table 4. 3: Proposed Framework — Procurement

Lean Principles	Pain Points	Lean Techniques And Tools	PCF Process Benchmarking	Proposed Initiatives
Define Value	(2)	Hoshin Kanri, TPS	4.2.3.1 Select suppliers (10288)	Establish procurement price control standards, and supplier price comparison and evaluation mechanisms to ensure that procurement prices meet the quality of the premise of the lowest cost.
Define Value	(2)	Hoshin Kanri, Kamishibai	4.2.1.2 Clarify purchasing requirements (10282)	Specify the technical requirements in the RFP according to the Technical specification provided by the design department.
Value Stream	(1)	A3, Kanban, Hoshin Kanri,SOP	4.2.1.6 Seek opportunities to improve efficiency and value (10286)	Develop advanced procurement management system, improve procurement process, streamline ineffective process and improve procurement efficiency.
Value Stream	(2)	VSM, A3, LPS,JIT	4.2.1.1 Develop procurement plan (10281)	Develop a reasonable tender procurement management plan based on mission objectives
Value Stream	(4)	VSM,SOP,PDCA,RCA,CF, Kamishibai	1.2.5.2 Perform job-specific roles mapping and value-added analyses (10050)	Establish a material management department, split the procurement rights and management rights, form a post-procedure to supervise the pre-procedure, avoid excessive concentration of rights and avoid integrity risks.
Value flow	(2)	VSM, A3	1.2.5.6 Develop role analysis and activity diagrams for key processes (10054)	Clarify the boundary scope of responsibility and authority, establish a transparent division of roles.
Value flow	(4)	Poke Yoke,PDCA, RCA , Kamishibai	1.2.5.6 Develop role analysis and activity diagrams for key processes (10054)	Conduct regular procurement audits to ensure that integrity risks are manageable.
Value flow	(3)	CF,PDCA,Kaize, RCA	1.2.5.3 Develop role activity diagrams to assess hand-off activity (10051)	Strengthen the interaction between the purchasing department and the design department.
Value Pulling	(2)	PDCA, Kaizen, TQM	4.2.1.4 Match needs to supply capabilities (10284)	Establish a Strategic supplier database to expand the supply chain resource reserve of high-quality resource manufacturers, suppliers and transporters.
Perfection	(1)	TIM, Kaizen	4.2.2 Develop sourcing and category management strategies (20973)	Carry out new procurement models, such as actively promoting CP procurement and DP model.
Perfection	(1)	PDCA, RCA ,Kaizen	4.2.2 Develop sourcing and category management strategies (20973)	Take the new procurement model to the strategic level and adopt different procurement strategies based on the quantity of materials purchased, lead time, and ease of acquisition.

Source: Author, 2023

Material Management Pain Points: (1) unclear management objectives; (2) serious waste; (3) No supplier management and assessment; (4) lack of financial security; (5) ineffective communication.

Table 4. 4: Proposed Framework — Material Management

Lean Principles	Pain Points	Lean Techniques And Tools	PCF Process Benchmarking	Proposed Initiatives
Define Value	(1), (2)	Hoshin Kanri,TPS,TQM	4.2.4.7 Research/Resolve order exceptions (10298)	Clarify the standards of material consumption management, sign a material management responsibility letter with project managers, establish an incentive mechanism, efficiently guarantee material supply, and control material consumption according to standard indicators
Value Stream	(1), (2)	Kanban ,A3, Andon	2.3.1.8.5 Design and manage product data, design, and bill of materials (16818)	Use BIM technology to accurately estimate material quantities and prepare detailed and accurate construction drawing budgets in a timely manner.
Value flow	(1)	VSM,A3	1.2.5.6 Develop role analysis and activity diagrams for key processes (10054)	Clarify the boundary scope of responsibility and authority, establish a transparent division of roles.
Value flow	(5)	CF,PDCA,Kaize, RCA	1.2.5.3 Develop role activity diagrams to assess hand-off activity (10051)	Proactive linkage with design, procurement and finance departments.
Value Pulling	(1), (2)	JIT,LPS, Pull Plan,PDCA	4.2.4.6 Reconcile purchase orders (10297)	Prepare timely material demand plan according to site construction progress needs, and purchase according to demand to avoid excessive material orders.
Value Pulling	(1), (2)	JIT,FIFO, Pull Plan,PDCA	4.4.3.2 Receive, inspect, and store inbound deliveries (10354)	Establish a material receipt (distribution) system and inventory count system to avoid excessive inventory.
Value Pulling	(1), (2)	JIT,Pull Plan,PDCA	4.4.3.7 Manage physical finished goods inventory (10359)	Reasonable arrangement of warehouse locations in each phase of construction to reduce the occurrence of multiple transportation at the construction site.
Perfection	(2)	SOP ,TQM, 5S, Kaizen, Hoshin Kanri	4.2.5.4 Monitor quality of product delivered (10302)	Strictly implement the system of receiving and inspecting the incoming materials to ensure that the quantity and quality of materials meet the requirements.
Perfection	(5)	Kaizen, PDCA, RCA	1.2.2.5 Develop partner/alliance strategy (16803)	Interact with suppliers in the execution process, organize regular meetings and take the initiative to coordinate to form a Strategic cooperation relationship.
Perfection	(3)	Kaizen, Kamishibai	4.2.5.2 Prepare/Analyze procurement and vendor performance (10300)	Adopt the method of "performance management" to regularly inspect and evaluate suppliers and continuously improve their service quality.
Perfection	(4)	Poke Yoke, Kaizen, Kamishibai	4.2.3.4 Manage contracts (10291)	Monthly tracking of material payment, proactive protection of suppliers' rights and interests, proactive avoidance of conflict and risk of supply disconnection.
Perfection	(4)	Kaizen,TIM	1.2.2.7 Develop innovation strategy (16806)	Union with the finance department to expand low-cost supply chain financial channels to meet the stability of material supply.

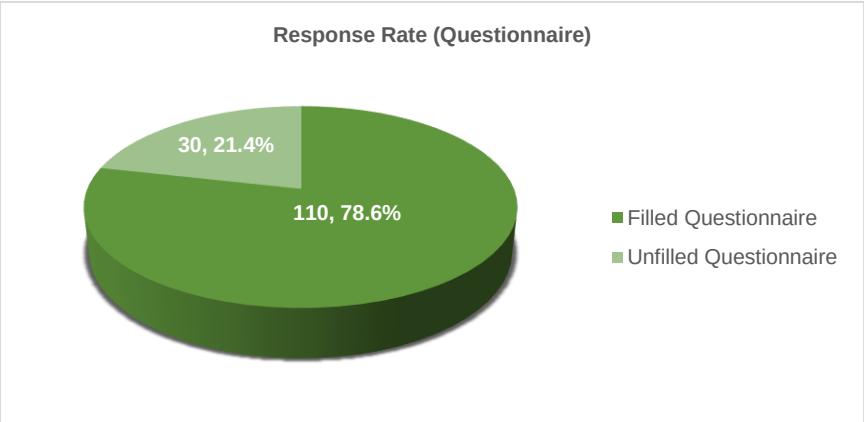
Source: Author, 2023

CHAPTER FIVE DATA ANALYSIS

5.1 Introduction

This phase focused on collecting feedback data from the unfrozen phase (not the changing and refreezing phase). The expected sample size was 140 and the actual number of questionnaire feedback data received was 110 (greater than 104), which satisfied the valid size of the sample. Overall, the actual sample data size collected was within the acceptable bias of this study, so the generated data analysis results were objective and valid.

Graph 5. 1: Questionnaire Response Rate



Source: Author, 2023, Data from Questionnaire Collection

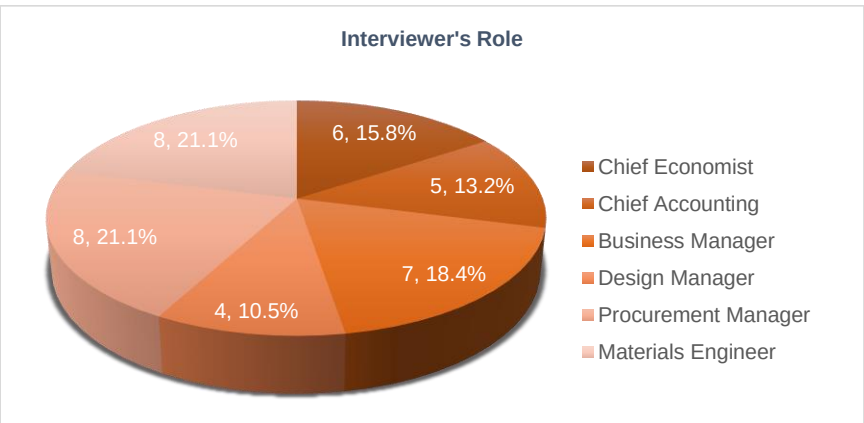
5.2 Data Analysis

5.2.1 Preliminary Diagnostic Validation

5.2.1.1 Interviewer's Background Analysis

Thirty-eight people participated in the interviews, and 11 were from the top, accounting for nearly 30%. The remaining 27 were heads of design, procurement and other departments.

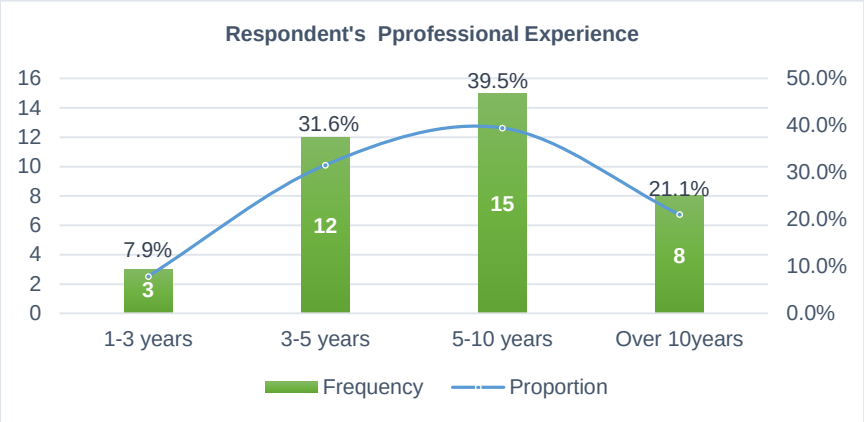
Graph 5. 2: Interviewer's Role Data Profile



Source: Author, 2023, Data from Appendix A No.1

The data shown in graph 5.3 shows that 39.5% of the interviewees had experience in this position ranging from 5 to 10 years. In addition, 21% of the interviewees had more than 10 years of experience in this position, which is sufficient to match the interviewer's management role.

Graph 5. 3: Interviewer's Professional Experience Data Profile



Source: Author, 2023, Data from Appendix A No.2

5.2.1.2 Preliminary Diagnostic Analysis

Table 5.1 demonstrates the problems in project management as perceived by the interviewers.

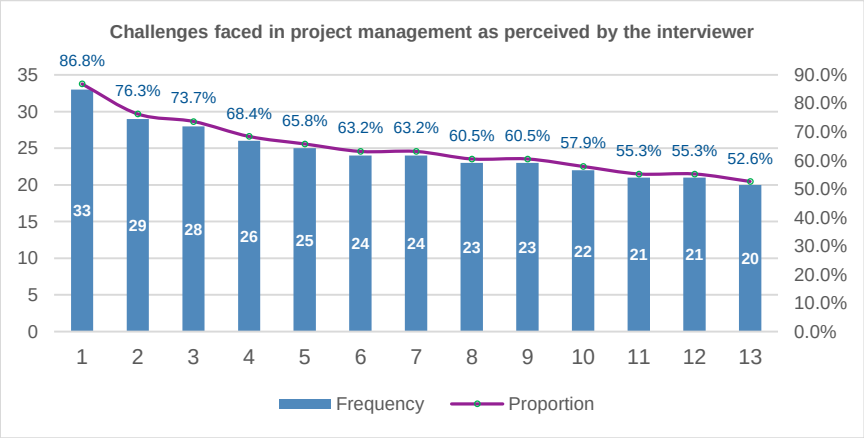
Table 5. 1: List of Questions from Interviewers' Feedback

No.	Description	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
1	Serious material waste	15	18	4	1	0
2	No construction drawing budget	14	15	4	3	2
3	Inaccurate material planning	12	16	5	2	2
4	The design department does not play a guiding role in cost management	10	16	5	4	3
5	BIM is not working as it should	11	14	7	3	3
6	High purchasing price, too low efficiency	13	11	6	6	2
7	Failure to pay funds on time as contracted	9	15	9	3	2
8	Lack of standardized management in BIM work	8	15	8	5	2
9	Procurement has Integrity issues	10	13	9	3	3
10	Insufficient interdepartmental linkage and guidance	8	14	7	5	4
11	The design department didn't develop the specification	9	12	8	6	3
12	Insufficient application of CP and DP modes	11	10	12	3	2
13	Lack of supplier management and assessment	8	12	9	6	3

Source: Author, 2023, Data from Appendix A No.3 (N=38)

Graph 5.4 shows the data ranking more visually. The authors ranked each issue in order from highest to lowest according to the percentage of each issue through the cluster chart. From the feedback data, many issues such as waste, construction drawing budget, material planning, BIM, procurement price, procurement time, CP and DP model application, and then to supplier management maintain a high consistency with the direction assumed by the authors.

Graph 5. 4: Questions Ranking Status



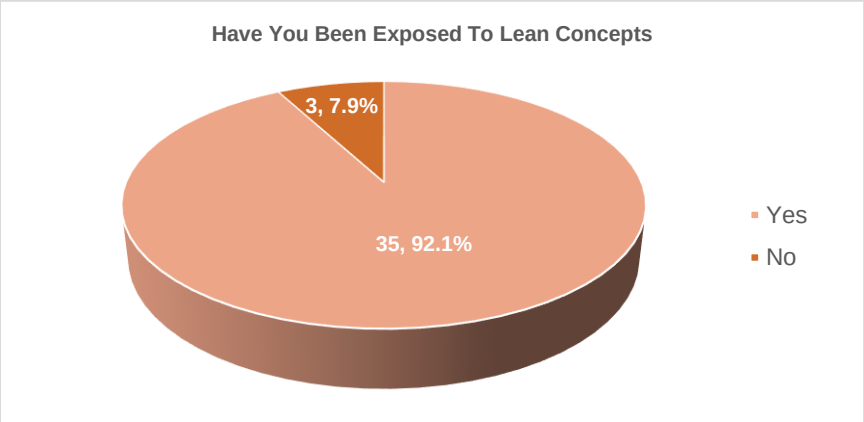
Source: Author, 2023, Data from Table 5.1- Appendix A No.3 (N=38)

5.2.1.3 Interviewer's Lean Knowledge Assessment

The data in graph 5.5 shows that 35 interviewees indicated that they had been exposed to Lean concepts, which is more than 92%, indicating that middle and senior managers are more or less knowledgeable about Lean-related topics.

This level of data is due to the company's quarterly promotion and training of Lean concepts, which of course only covers Lean basics at the moment. Subsequent training should deeply expand more Lean knowledge and techniques and Lean technologies, such as training all employees on how to apply Lean techniques, which will help Lean knowledge and better apply to project management practices in a timely manner.

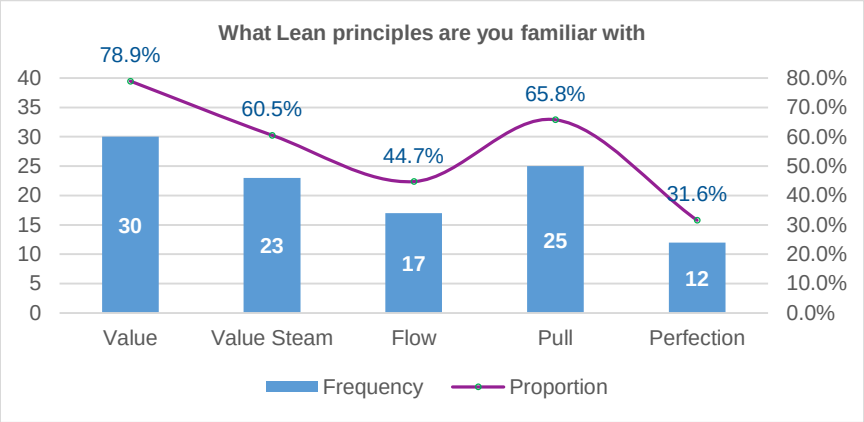
Graph 5. 5: Interviewer Knowledge of Lean Concepts



Source: Author, 2023, Data from Appendix A No.4 (N=38)

The data in graph 5.6 shows that more than 60% of the interviewees are familiar with the three Lean principles of "value," "value stream," and "pull," with 78.9% and 60.5% respectively. This also indicates that middle and senior managers have some knowledge of Lean.

Graph 5. 6: Interviewer Familiarity with Lean Principles



Source: Author, 2023, Data from Appendix A No.5 (N=38)

Table 5.2 shows the feedback data obtained from the interview script No. 6.

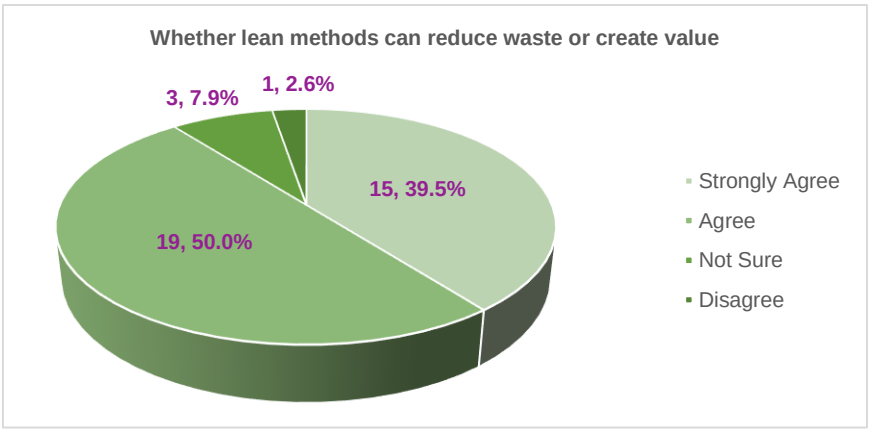
Table 5. 2: Interviewers' Feedback on Lean Knowledge

No.	Description	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
1	Lean methodology can help reduce waste or create value	15	19	3	1	0
2	Lean management is being implemented at work	7	18	6	4	3

Source: Author, 2023, Data from Appendix A No.6 (N=38)

The data in graph 5.7 shows that 34 interviewees believe that lean methodology help reduce waste or create value, a percentage of nearly 90%, indicating that middle and senior managers recognize the positive effects of lean techniques and have reached a high degree of unity of opinion.

Graph 5. 7: Interviewers' Views on the Role of Lean Thinking

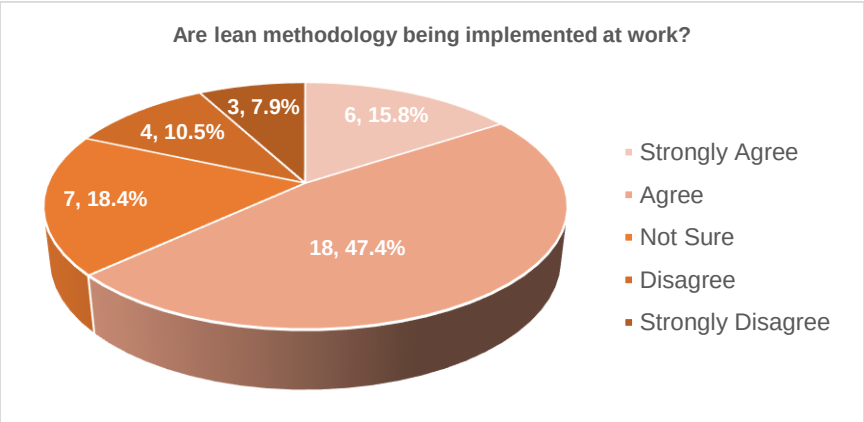


Source: Author, 2023, Data from Appendix A No.6 (N=38)

The data in graph 5.8 shows that 25 interviewees believe that Lean methods are being implemented in their usual management, which is more than 60%. The Lean knowledge awareness data in graph 5.6 is at a comparable level (also more than 60%), but the reality of the results shows that waste is still high, which indicates that Lean methods are not yet fully functioning in the project department or that the depth of understanding of Lean methods

needs to be strengthened.

Graph 5. 8: Interviewers' Views on the Practical Application of Lean Methodology



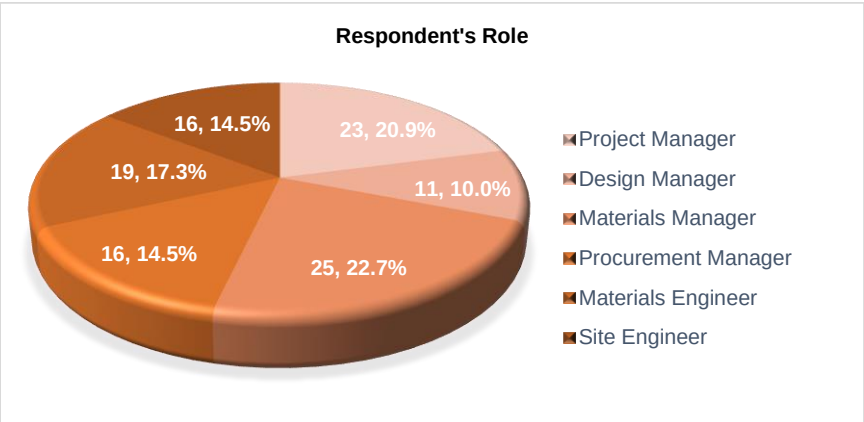
Source: Author, 2023, Data from Appendix A No.6 (N=38)

5.2.2 Proposed Framework Evaluation

5.2.2.1 Respondent's Background Analysis

The data in graph 5.9 shows that of the 110 people who participated in the questionnaire, project managers (23), material managers (25), material engineers (19), and field engineers (16), which account for more than 75% of the four positions, a result that indicates that most respondents are from the front line of the project department, so this group is the ideal target for this study.

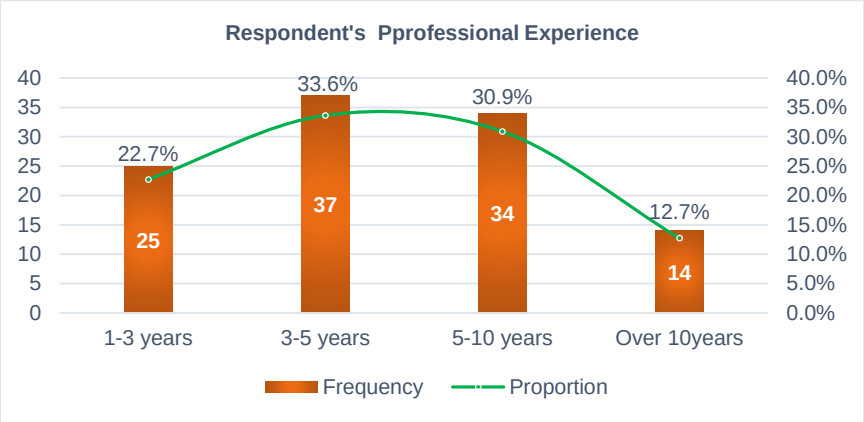
Graph 5. 9: Respondent's Role Data Profile



Source: Author, 2023 Data from Appendix C No.1

The data in graph 5.10 shows the work experience of the respondents in their current positions. 37 (33.6%) have 3-5 years of experience, 34 (30.9%) have 5-10 years of experience, and 14 (12.7%) have more than 10 years of experience, accounting for more than 70% of the respondents. It is clear that most engineers and project managers have sufficient work experience in their current positions.

Graph 5. 10: Respondent's Professional Experience Data Profile



Source: Author, 2023 Data from Appendix C No.2

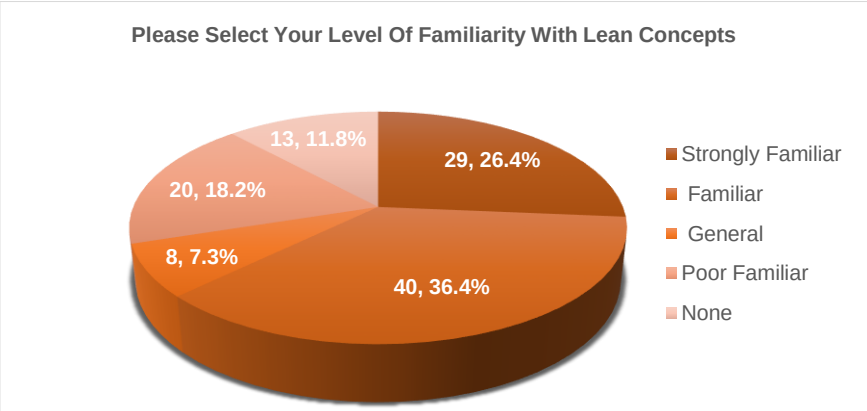
5.2.2.2 Awareness Assessment Lean Knowledge

This section focuses on assessing the awareness of key managers in the project department on the terminology and principles of Lean concepts, the application of Lean management, and the importance and significance of Lean thinking in management through these 4 dimensions in order to verify that the proposed framework implementation has the foundational conditions.

One of the important questions in this survey asked respondents to choose their level of familiarity with the term "Lean" from very familiar to unfamiliar.

Graph 5.11 shows that 69 of the 110 respondents (more than 60% of the total) had good knowledge of the term "Lean" (29 said they were very familiar with it and 40 said they were familiar with it). In addition, the results show that approximately 30% of respondents had little to no knowledge of Lean. Of these, 20 respondents reported very limited knowledge of Lean (18.2%) and 13 respondents reported no knowledge at all (11.8%).

Graph 5. 11: Respondent's Level of Awareness about Lean Concepts



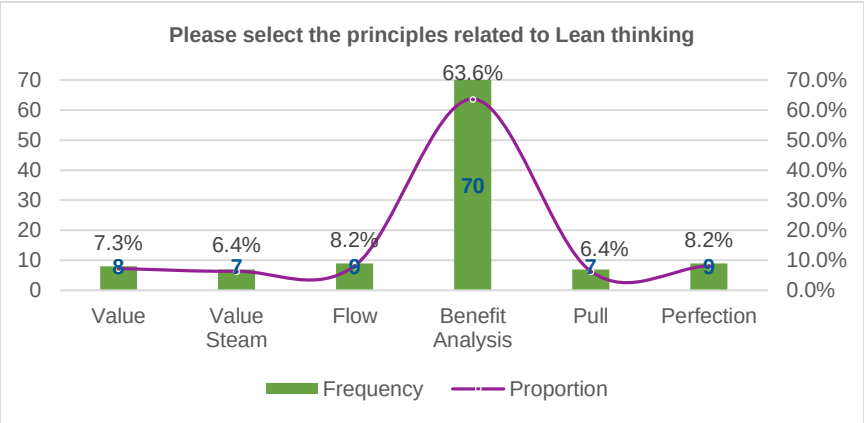
Source: Author, 2023, Data from Appendix C No.3

The above data shows the respondents' level of awareness of Lean concepts, thus reflecting a good awareness and knowledge base of Lean among project managers.

To assess the depth of Respondents' knowledge of Lean in a multidimensional way, the authors set a question on Lean principles and asked Respondents to select what was not relevant to the Lean principles listed in the options: value, value Steam, flow, Benefit analysis, pull, and perfection. Among them, "Benefit analysis" is the only correct option.

As the results in graph 5.12 show, 70 people made the correct choice, indicating that at least more than 60% of Respondents have a good level of Lean knowledge, which is comparable to the data presented in graph 5.11. About 36% made the wrong choice, indicating that at least 30% of Respondents have poor lean knowledge.

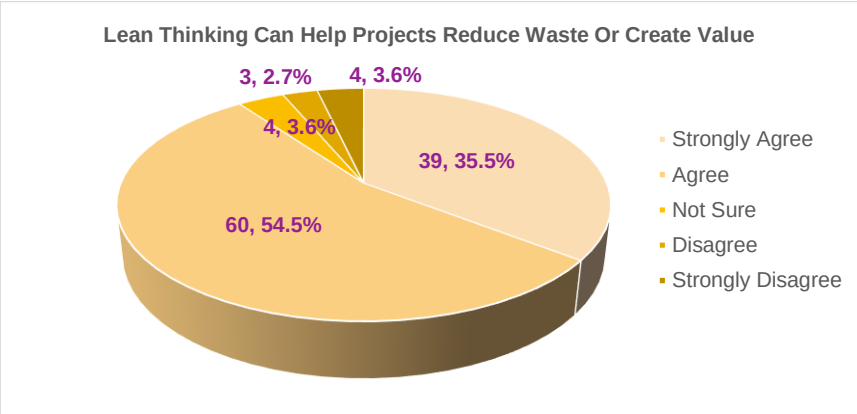
Graph 5. 12: Respondent's Level of Awareness about Lean Principles



Source: Author, 2023, Data from Appendix C No.4

Next, the authors assess whether lean thinking can play a positive role in project management. Graph 5.13 shows the results of the question "Lean thinking can help projects reduce waste or create value". 35.5% of the participants strongly agreed with this statement and 54.5% agreed with it. Overall, it seems that 90% of Respondent agree that Lean thinking has a positive effect on project management, which is a very high percentage. On the other hand, only 6.4% of Respondents disagreed and strongly disagreed with this statement, which is a relatively low percentage.

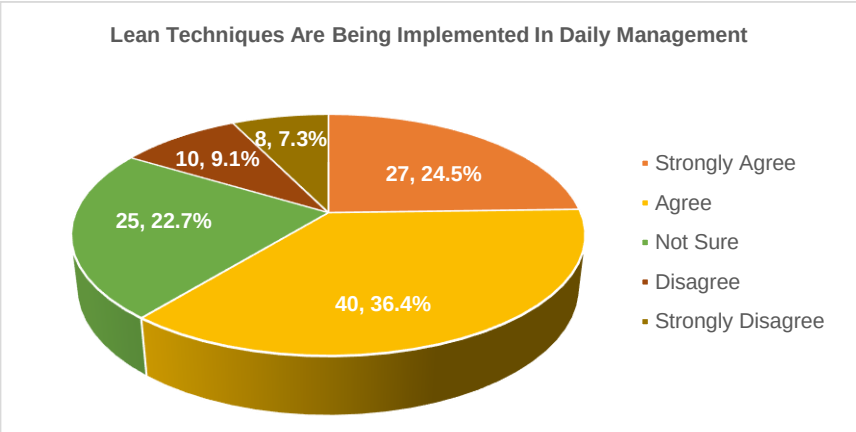
Graph 5. 13: Respondent's Views on the Role of Lean Thinking



Source: Author, 2023, Data from Appendix C No.5

In preparation for the launch of the proposed framework, it is necessary to understand in advance the extent to which Lean techniques are being applied in the actual management of projects. The data in graph 5.14 shows that 27 respondents strongly agreed and 40 respondents agreed, with an overall 60.9% of respondents indicating that they are implementing Lean techniques in their daily work, indicating that the proposed framework incorporating Lean principles has the basis for implementation. On the other hand, 16.4% strongly disagreed and disagreed with the statement, which is a very small percentage and has little impact on the implementation of the new program.

Graph 5. 14: Respondents' Views on the Practical Application of Lean Techniques



Source: Author, 2023, Data from Appendix C No.6

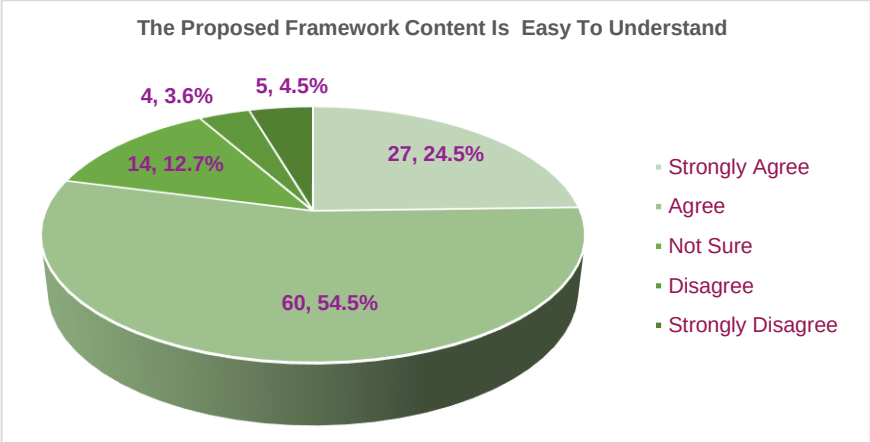
5.2.2.3 Proposed Framework Feasibility Assessment

For this study, it is necessary to evaluate whether the proposed framework is ready for implementation in terms of the following dimensions. For example, whether the framework can be understood enough by project managers, whether there are logical fallacies, acceptability to other project managers, feasibility, and the extent to which project managers are willing to support the implementation of the framework.

The data in graph 5.15 shows that 27 respondents strongly agreed and 60 respondents agreed, for a total of approximately 79% of respondents who said they could understand the content of the proposed framework, and less than 10% of respondents who said they could not understand the content of the framework.

Overall, the data show that the proposed framework is easy to understand.

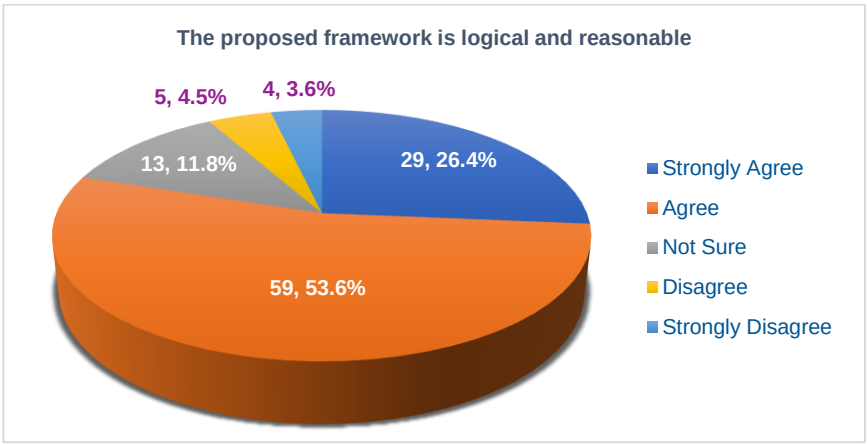
Graph 5. 15: Respondents' Level of Understanding of the Proposed Framework



Source: Author, 2023, Data from Appendix C No.7

The data in graph 5.16 show that 88 respondents found it reasonable (80%) that there were no logical problems with the content of the proposed framework, and only roughly 8% of respondents indicated that there were some problems with the content of the framework, indicating that most people did not think there would be logical obstacles to the implementation of the proposed framework.

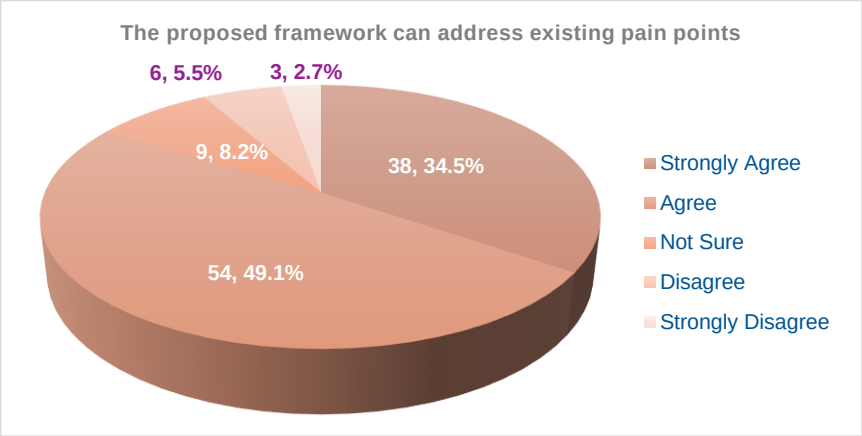
Graph 5. 16: Respondents' Views on the Rationality of the Proposed Framework



Source: Author, 2023, Data from Appendix C No.8

The data in graph 5.17 shows that 34.5% of respondents strongly agreed and 49% agreed, two sets of data that indicate that more than 83% of respondents believe the proposed framework can address existing pain points, a result that is significant for the proposed framework implementation.

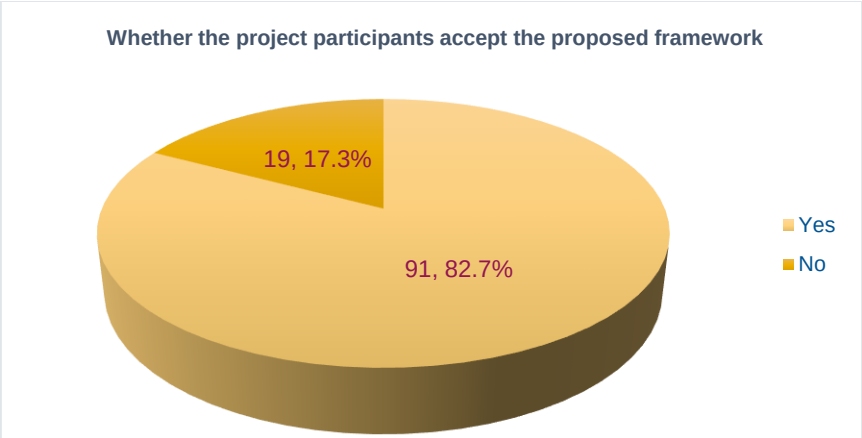
Graph 5. 17: Respondents' Views on the Validity of the Proposed Framework



Source: Author, 2023, Data from Appendix C No.9

The data in graph 5.18 shows that 91 respondents indicated that the proposed framework is acceptable to other program managers, which is more than 82% and the result is positive, which indicates that the acceptability of the proposed framework is relatively high.

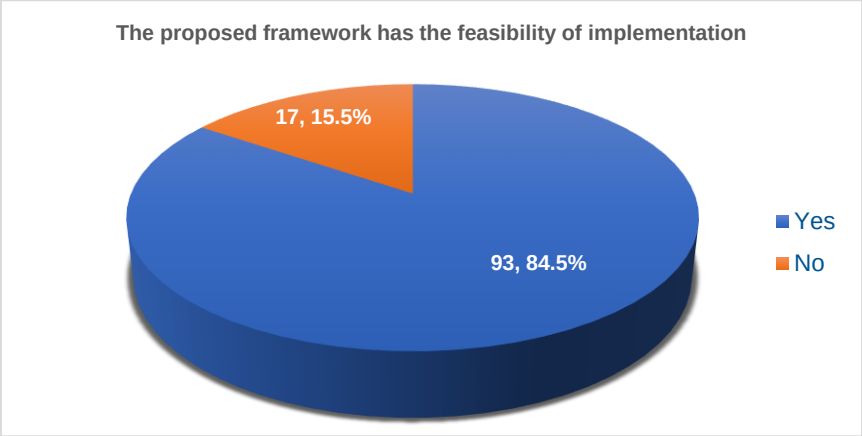
Graph 5. 18: Respondents' Views on the Acceptability of the Proposed Framework



Source: Author, 2023, Data from Appendix C No.10

The data in graph 5.19 shows that 93 respondents indicated that the implementation of the proposed framework is feasible and 17 respondents indicated that there are problems with the implementation of the proposed framework, which means that more than 84% of the majority believe that the proposed framework is feasible to implement, but there are several issues that need to be addressed in order to better implement the proposed framework, such as the commitment of the project managers (to ensure that the implementation of the proposed framework is highly targeted), and a guide to explain the lean tools (to help other project managers better understand the lean techniques and tools and improve the efficiency of the implementation).

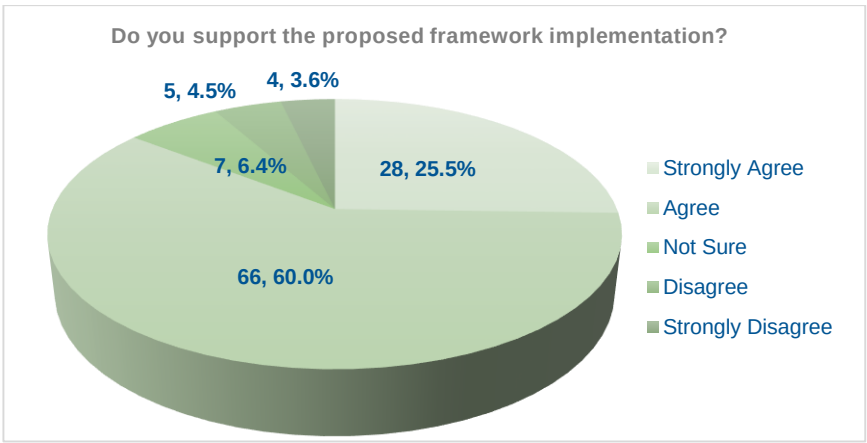
Graph 5. 19: Respondents' Views on the Implementability of the Proposed Framework



Source: Author, 2023, Data from Appendix C No.11

The data in graph 5.20 shows that 28 respondents said they were very willing to support it and 66 respondents said they were willing to support it, which indicates that more than 85% of the respondents were willing to support the implementation of the proposed framework in their daily management, which has a relatively high public opinion base and shows that project managers are willing to implement the proposed framework to improve the problems in their organizations.

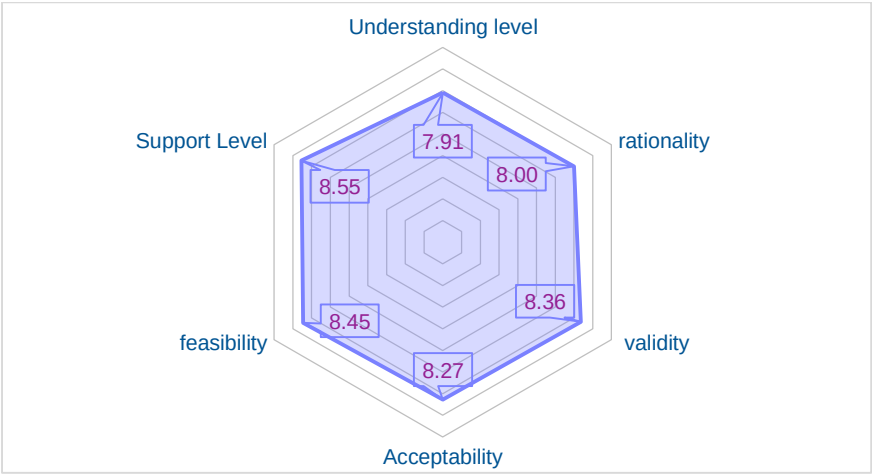
Graph 5. 20: Respondents' Support for the Implementation of the Proposed Framework



Source: Author, 2023, Data from Appendix C No.12

Graph 5.21 shows very visually the data of six dimensions to verify the feasibility of the proposed framework: the level of understanding, the rationality of the proposed framework, the effectiveness of the proposed framework, the acceptability of other managers, the implementability of the proposed framework, and the willingness of project managers to support it. Each statistic is assigned a different score depending on its percentage, if the percentage is 100%, then it will get 10 points, and so on for other percentages to get the displayed results in graph 5.21.

Graph 5. 21: Framework Multidimensional Assessment



Source: Author, 2023, Data from Appendix C

In terms of the scores of the six dimensions, the overall scores are relatively high, and most of the respondents' feedback data are positive and positive.

In the questionnaire on the implementability of the proposed framework, the majority (84.5%) of respondents approved, but at the same time raised some two issues that need to be addressed: the commitment of project managers, and the development of a lean technical description guide. The main purpose of these two issues is to help the proposed framework have a deeper basis for implementation, and the questions are positive and the proposed framework should be refined based on this input.

In general, the data in graph 5.17 leads to a very objective conclusion that the proposed framework is feasible.

CHAPTER SIX CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This thesis proposes a framework that can be used in project management practices to improve the performance of item purchase material and site material management by introducing lean principles, adopting a BPM approach, and benchmarking the proposed framework against the PCF process to form a systematic solution. The study consisted of two phases. In the first phase, interviews were conducted with senior and middle management of the company with the aim of conducting an initial validation of the pain points in the area of on-site procurement and on-site material management. After identifying the key pain points in this area, a proposal framework with a lean philosophy was developed with the aim of addressing and improving the existing pain points. In the second phase, a questionnaire was given to project managers to validate the proposal framework from a 6-dimensional perspective.

The first phase of interviews proved that interviewees clearly indicated that there are a lot of pain points in BIM, procurement and material management, with over 60% of interviewees agreeing that there are problems in areas such as material waste (86.8%), construction drawing budget (76.3%), material planning (73.7%), BIM (65.8%), high procurement price and time (63.2%), and procurement discipline (60.5%). such data results also maintain a high degree of consistency with the authors' initial judgment, and illustrate that although the company has been improving many management issues, the existence of these problems still project management thorny issues.

At the same time, interviewees were communicated the extent of their knowledge of Lean, the role of Lean thinking for management, and the extent of Lean implementation. From the data results, over 90% of the interviewees indicated that they have been exposed to Lean ideas, and 60% have a relatively good understanding of Lean principles, which is a positive effect of Lean fundamentals training, but still lack of in-depth Lean management knowledge mastery. Over 90% of interviewees believe that Lean thinking can have a positive effect, and approximately 63% believe that Lean is being implemented in daily management. These figures also indicate that Lean Management has some basis for implementation on the project.

In response to the pain points identified in the interviews, the authors developed a proposed framework with a lean philosophy, which aims to target the challenges faced in the three areas of BIM, procurement, and materials management. Thus, the ultimate goal of the proposed framework is to implement the Lean-inspired framework into project management practices to improve the performance of project procurement and on-site materials management. The proposed framework presents a set of tools and techniques for each of the

five Lean principles and links them to specific business processes through a BPM approach. In this way, a series of initiatives are developed to address the factors that limit performance in project procurement and on-site materials management in a targeted manner.

In this paper, the proposed framework was verified in all aspects around six dimensions, including comprehensibility, rationality, validity, acceptability, feasibility, and managerial support of the proposed framework. (1) 87 respondents felt that they could understand the content of the proposed framework (79.1%), and the framework comprehensibility was defined as 7.91. (2) 88 respondents indicated that the design of the proposed framework content was reasonable (80%) and there were no logical problems, and the framework reasonableness was defined as 8.0. (3) 92 respondents indicated that the proposed framework was relevant for addressing project procurement and on-site material management (83.6%) and can address existing pain points, and the validity was defined as 8.36, the significance of this data is significant. (4) 91 respondents felt that the proposed framework was acceptable to other project managers (82.7%), and acceptability was defined as 8.27. This data also proves that the proposed framework is viable. (5) 93 respondents felt that the proposed framework was feasible to implement (84.5%), with an implementability rating of 8.45. Nevertheless, they also suggested that two necessary issues should be addressed before the proposed framework can be implemented, such as the commitment of project managers, the development of an explanatory guide to explain the Lean tools, and the resolution of potential implementation barriers to further improve the implementability of the proposed framework. (6) 93 respondents indicated their willingness to support the application of the proposed framework to project management practices (85.5%), which is a high percentage and indicates that project managers believe that the proposed framework can bring benefits to project management practices, with manager support defined as 8.55.

In summary, the proposed framework is a systematic solution that incorporates lean concepts and is supported by the data in all six dimensions above. The framework can be targeted to address pain points and challenges in project procurement and site materials management, and is conducive to promoting performance improvement in project procurement and site materials management.

6.2 Research Implications

6.2.1 Theoretical Implications

The proposed framework is an effective solution to address the wastefulness of project procurement and on-site material management, which can help projects to gain more benefits in procurement and on-site material management and ultimately achieve the stated research objectives of this thesis. At the same time, this study adds to the referenceable literature on

project procurement, on-site materials management, and lean management in the field of building construction.

First, this study adopted an action research approach. Action research method is a common research method to solve organizational development problems, and it is mostly used in the field of education and teaching in niche applications, while this study has a new and expanded application in procurement and on-site material management in the field of building construction, which provides a new vision and ideas in the methodological application of research in this field, and adds a referenceable literature in this field.

Second, this study integrates knowledge of lean thinking and BIM technology in the development of the proposed framework, expanding on existing research, and the relationship between BIM technology and lean technology is that they can make each other work (Rahman & Belayutham, 2022). BIM technology is seen as a "lean tool" in the eyes of the building construction industry that enables multidimensional management and acts as a baton to help establish goals for project procurement and site materials management. BIM technology is considered as a "lean tool" in the eyes of the construction industry, which enables multidimensional management and acts as a baton to help establish goals for project procurement and on-site materials management, which provides a reference document to solve the painful problems in this field.

Third, this study proposes a process-on-process benchmarking based on cross-industry PCF process framework for project procurement and materials management pain points, with the goal of identifying best practices by using benchmarking analysis in process work to continuously identify and weed out ineffective activities in the organization. Create concise processes that enhance clarity and transparency to increase the drive for continuous improvement in organizational performance. This is one approach to continuous improvement in lean practices for project procurement and materials management, which provides a referenceable literature for subsequent research in this area.

Finally, since this study is only a case study within the company and no data information was collected from external units, the generalizability of the replication is deficient, but the findings of the case study can provide a reference for other companies facing the same problem.

6.2.2 Management Implications

Based on the results of the study, we are confident that the proposed framework presents new guidelines for how project departments can apply lean management thinking in procurement and on-site materials management, which will lead project managers more easily to success.

First, the company's other projects at the facility can leverage the success of this study to

develop appropriate action plans and then implement the proposed framework. As described in the study's findings, the proposal framework is very specific to the pain points of the study cases and provides a more scientific basis for project managers to manage, which is not in fact a paper exercise. Feedback from project managers and other front-line managers during the development of the proposal framework greatly enhanced its credibility and validity, and allowed the project team to avoid and improve existing conflicts and pain points through the proposed initiatives to achieve greater benefits and thus reduce project construction costs.

Secondly, the proposal framework can help projects solve problems systematically, unlike the old practice of "treating the head when the head hurts and treating the foot when the foot hurts", which always habitually proposes point solutions to solve problems encountered each time. Lean technology and practice are closely linked as an organic whole, and both need to resonate with each other in practice to play a holistic role, which also requires the project managers to work together in the process of implementing the proposed framework, with the same goal, to implement in the promotion and improve in the implementation, so as to bring more chances of success to the project.

Third, from the communication with the project managers, we got some of their opinions on the proposed framework, and they thought that this systematic solution provided them with a good inspiration and guidance in their subsequent project management, and they all expressed their willingness to support the pilot implementation of this framework in the projects they managed. During the research process, project managers realized the "why", understood the "how", and saw the "what's in it for them", which greatly enhanced their willingness to implement the proposed framework in the future. The willingness to implement the proposed framework in the future was greatly enhanced.

In summary, the results of this study support the theoretical benefits of Lean thinking in helping to improve the effectiveness of project procurement and on-site materials management. It also offers a lot of hope for many project managers.

6.3 Research Limitations

Although the author has made a lot of efforts in this thesis phase, there are still some limitations:

First, due to time constraints, the findings of this dissertation are only in the first phase of action research. There is a lack of data feedback on the implementation of the second phase of the framework, and it is important to observe and reflect on the framework in continuous practice in the future to further improve it.

Secondly, this thesis is based on a single case study, which only collected a sample of 110 data from the company's front-line project managers, lacking data collection from external companies, and the overall sample size is insufficient, which limits the possibility of extending

the case study findings to other companies and can only provide recommendations for other companies.

Finally, the feedback data from the questionnaire suggest that the proposed framework needs further refinement and needs to address the issues of project manager commitment and lean technology description guidelines.

6.4 Future Research Recommendations

Establishing a framework for problem solving in the theoretical phase is a good start, but further research is needed to better adapt it for real problem solving:

First, based on the questionnaire feedback, the proposed framework was improved: one is the project manager's commitment, which is achieved by signing a target responsibility letter. The other is a lean technique description guide to sort out the common working scenarios of lean knowledge, to help project managers identify different implementation environments of lean techniques and to improve the implementability of the framework.

Second, expand the sample size and scope of the case studies to include other companies in the construction industry, collect data on relevant knowledge more broadly, and enhance the generalizability of the case study results to most companies in the construction industry.

Third, according to the action research steps, the second phase should be carried out for no less than six months (the construction industry has a long cycle with a lag from action implementation to data feedback). In the last week of the action plan, feedback data on the implementation of the action is collected through a questionnaire (change phase). In the third phase of action research (freeze phase), effective knowledge or results are finally output through continuous observation, reflection and continuous improvement.

Fourth, before the implementation of the framework, special training on lean knowledge will be conducted, and a small test will be conducted at the end of the training to test the training results, with a training cycle of no less than 1 month (1 time per week). The special training should cover all members of the project managers, labor teams, and key material suppliers, in order to improve the awareness and capability of workers and project managers on lean management practices and to guarantee that the proposed framework can be systematically implemented in project management.

Finally, this study can be extended to examine the control of objectives and performance indicators in design, procurement, and on-site materials management, which is necessary for project management.

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APPENDICES

APPENDIX A – [Interview Guide]

In order to verify how well middle and senior managers understand the design, project procurement, and materials management situation, and how familiar they are with Lean knowledge, six main areas of questions were designed to obtain feedback data.

1. What is your current position in the company?

2. How long have you been in this role?

3. What do you think are the current challenges or problems in design, procurement and material management? (You can make an assessment based on your knowledge)

No.	Description	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
1	Serious material waste					
2	No construction drawing budget					
3	Inaccurate material planning					
4	The design department does not play a leading role					
5	BIM is not working as it should					
6	High purchasing price, too low efficiency					
7	Failure to pay funds on time as contracted					
8	Lack of standardized management in BIM work					
9	Procurement has Integrity issues					
10	Insufficient interdepartmental linkage and guidance					
11	The design department didn't develop the specification					
12	Insufficient application of CP and DP modes					
13	Lack of supplier management and assessment					

4. Have you been exposed to Lean concepts?

5. What Lean principles are you familiar with?

6. In your opinion, can Lean methods reduce waste or create value? Are Lean methods being implemented in normal work management? (You can make an assessment based on your knowledge)

No.	Description	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
1	Lean methodology can help reduce waste or create value					
2	Lean management is being implemented at work					

APPENDIX B – [Performance Limiting Factors]

Based on some of the author's practical experience in project management, and the feedback received during the interview interactions, some of the constraints on the performance of the design, procurement and materials management roles have become more defined:

Table Appendix B. 1: Performance Limiting Factors about Design

No.	problems	Performance Limiting Factors
1		BIM does not play the role of 4D, 5D.
2		The design department did not develop the specification of the procurement needs
3		The target requirements of BIM modeling are rather vague
4		BIM does not play a leading role in procurement, materials and cost management
5		BIM does not connect all business lines
6		Insufficient visual management of BIM

Source: Author, 2023

Table Appendix B. 2: Performance Limiting Factors about procurement

No.	problems	Performance Limiting Factors
1		Many categories of materials are not purchased separately
2		CP implementation rate is relatively low
3		DP application rate is insufficient
4		Material purchase price is too high
5		There are too few quality suppliers available
6		Excessive concentration of power
7		Lack of disciplinary oversight
8		The technical specifications of the materials to be purchased are too vague
9		The procurement process is too lengthy
10		Unreasonable setting of procurement tender control price
11		Unclear responsibilities and authority, unclear division of labor

Source: Author, 2023

Table Appendix B. 3: Performance Limiting Factors about material management

No.	problems	Performance Limiting Factors
1		No timely preparation of construction drawing budget and vague material consumption target
2		Inadequate management system, unclear responsibilities and poor execution
3		Inaccurate material planning
4		Material acceptance is not strict
5		Defective quality of materials provided by suppliers
6		Confusion in the management of receiving and issuing materials
7		No in-process inventory count
8		No process comparison analysis and process corrective measures
9		Warehouse management is chaotic, there are always a lot of unused materials in stock
10		Poor quality of materials provided by suppliers
11		Material payment is not timely, suppliers always cut off supply
12		The location of the warehouse at the construction site is not reasonable
13		No supplier management and assessment
14		Rework and demolition occur frequently
15		Long idle time of equipment (excavator, car crane, tower crane)

Source: Author, 2023

APPENDIX C – [Questionnaire]

Dear Ms. /Mr.,

Hello! First of all, thank you very much for taking the time to fill out this questionnaire! We are conducting one research on project procurement, this questionnaire is anonymous, the information you fill in is only for the research team to do statistical analysis, please feel free to fill in! There is no correct or incorrect answer, please fill in the questionnaire according to your own true will and understanding of the actual situation, thank you for your support.

Please tick [√] the box that matches your answer to the questions.

Section One: Respondents' Background Information

1. What is your current role in the project department?

Project Manager □ Design Manager □ Materials Manager □

Purchasing Manager □ Materials Engineer □ Site Engineer □

2. How many years of professional experience do you have?

1-3 years □ 3-5 years □ 5-10 years □ Over 10years □

Section Two: Lean thinking-related knowledge assessment

3. Please select your level of familiarity with Lean concepts.

Strongly Familiar □ Familiar □ General □ Poor Familiar □ None □

4. Please select a principle that is not related to Lean thinking.

Value □ Value Stream □ flow □ Benefit Analysis □ Pull □ Perfection □

5. Lean thinking can help projects to reduce waste or creation value.

Strongly Agree □ Agree □ Not Sure □ Disagree □ Strongly Disagree □

6. In your opinion, Lean methodology are being implemented in daily management.

Strongly Agree □ Agree □ Not Sure □ Disagree □ Strongly Disagree □

Section Three: Proposed Framework Evaluation

7. The proposed framework content is relatively easy to understand.

Strongly Agree □ Agree □ Not Sure □ Disagree □ Strongly Disagree □

8. The proposed framework is reasonable and does not contain logical errors.

Strongly Agree □ Agree □ Not Sure □ Disagree □ Strongly Disagree □

9. The proposed framework are effective solutions that can address existing pain points.

Strongly Agree □ Agree □ Not Sure □ Disagree □ Strongly Disagree □

10. Do you think the proposed framework will be accepted by other project participants in project management?

Yes □ No □

11. Do you think proposed framework is feasible to implement in project management? Are there any difficulties in the implementation process?

Yes □ No □

Other difficulties and problems:

12. As a key participant in project management, you are willing to support the implementation of the proposed framework in project management.

Strongly Agree □ Agree □ Not Sure □ Disagree □ Strongly Disagre